1-1-2002

Heritability estimation in maize using midparent-offspring regression

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by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Plant Breeding

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Iowa State University

Ames, Iowa

2002

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INTRODUCTION

Heritability estimates are a measure of the relative importance of genetic and nongenetic factors in the expression of the phenotype (Fehr, 1991). Traits with higher broad-sense heritability have either less environmental or less nongenetic factors affecting phenotype expression than traits with lower heritability.

Plant breeders are interested in precise heritability estimates with the least amount of resource investment. Heritability estimates allow breeders to gauge the amount of resources and time necessary to realize improvement for the characteristic in the population under study. Different types of heritability estimates can be computed that give variable results depending upon the relatives measured and if estimates of additive genetic and dominance variances are available.

This study estimated narrow-sense heritability using midparent-offspring regression in maize [*Zea mays* L.]. Traits measured were yield, plant height, ear height, and tassel branch number. Midparent-offspring regression was chosen because the regression coefficient is a direct estimate of heritability. Full-sib family means were regressed on midparent values to obtain the heritability estimates.

LITERATURE REVIEW

Heritability

The question of whether the difference in phenotype of related organisms originates from genetic or environmental influence led to the idea of heritability. Nyquist (1991) defines heritability as a measure of the relative importance of heredity. Early papers by plant breeders used the term heritability in the descriptive sense but it was Fisher in 1918 that described heritability in the statistical sense of the quantitative relationship between relatives (Bell, 1977). Fisher showed that the regression of offspring on a parent, a measure of heritability, is given by the ratio $\sigma_G^2 / 2\sigma_P^2$ where σ_G^2 is the additive genetic variance and σ_P^2 is the total variance (genetic and nongenetic) in the population. Lush (1940) was the first to label the fraction of the observed variance caused by differences in heredity as heritability (Bell, 1977).

Heritability interests plant breeders because traits with higher heritability can be improved more rapidly utilizing fewer resources than traits with lower heritability. Heritability also allows breeders to predict gain from different selection methods using the gain equation.

Heritability can be defined as either broad-sense or narrow-sense. Broad-sense heritability $\left(h_b^2\right)$ is the ratio of the total genotypic variance $\left(\sigma_G^2\right)$ to the total phenotypic variance $\left(\sigma_P^2\right)$ ($h_b^2 = \sigma_G^2 / \sigma_P^2$). The total genotypic variance is the sum of the additive genetic, dominance, and epistatic variances ($\sigma_G^2 = \sigma_A^2 + \sigma_D^2 + \sigma_I^2$). The total phenotypic variance is the sum of the genotypic, environmental, and the genotypic-by-environmental variances ($\sigma_P^2 = \sigma_G^2 + \sigma_E^2 + \sigma_{GE}^2$). Narrow-sense heritability $\left(h_n^2\right)$ is the ratio of additive genetic variance to the total phenotypic variance ($h_n^2 = \sigma_A^2 / \sigma_P^2$). Additive genetic variance (σ_A^2), interests plant breeders because that is the portion of the genotype passed to the next generation (Hallauer and Miranda, 1988).

Heritability definitions exist in multiple contexts and multiple levels (Hanson, 1963). Heritability estimates must be defined relative to the trait of interest, the population, the environment, and the experimental unit because these factors can affect the estimate

(Nyquist, 1991; Falconer and McKay, 1996). Gene frequencies affect all genetic components, and may fluctuate from one population to another yielding different heritability estimates of the same trait. Any change in the environmental variance influences the denominator of the heritability estimate. The experimental unit measured affects the precision of the heritability estimate. In plant breeding experiments, the experimental unit of calculation may be individual plants, plot means, progeny means, or entry means across replications and environments. Precision increases as the number of plants and environments measured in the experimental unit increases; i.e., entry means give more precise heritability estimates than individual plants.

Midparent-Offspring Regression

Fisher (1918) suggested the use of parents and offspring to estimate heritability using the relationship $\sigma_G^2 / 2\sigma_P^2$. Lush (1940) offered a practical application of Fisher's ideas. Lush (1940) examined different methods to estimate heritability and concluded the relationship between relatives was the most useful. Of the different relationships between relatives, Lush determined the regression of the offspring on dam, or regression of the offspring on parent, gave the most useful estimate of heritability.

In parent-offspring regression, researchers examine two groups of individuals, the parent and the offspring or mean of the offspring. Midparent-offspring regression differs from parent-offspring regression in that both parents are measured and the mean of the parental values is used for calculations. Assuming parents X_1 and X_2, the midparent value is calculated as the average of the parental values $X_{\bar{P}} = [(X_1 + X_2)/2]$. The level of relation between individuals determines the genetic covariance (Falconer and Mackay, 1996). For midparent-offspring regression the genetic covariance contains half of the additive genetic variance ($Cov_{MPO} = ½\sigma_A^2$).

Least Squares Regression

Midparent-offspring regression can be a straightforward process with balanced data; i.e., meaning equal numbers of offspring are measured for each family. With balanced data, the statistical model is $Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i$ (Kempthorne and Tandon, 1953; Fernandez and Miller, 1985; Nyquist, 1991),

where

Y_i = mean of progenies of ith family;

β_0 = intercept;

β_1 = regression coefficient;

X_i = midparent value of ith family; and

ε_i = random error, independently and normally distributed with zero mean.

Regression is the ratio of the standard deviation of XY to the variance of X where X is the independent variable, the midparent value in this case, and Y is the dependent variable, the offspring (Equation 1).

$$\text{Eqn. 1:} \quad b = \frac{\sigma_{XY}}{\sigma_X^2} = \frac{Cov_{MPO}}{\sigma_X^2}.$$

The midparent value is the average of the parental values X_1 and X_2 (Equation 2) so the variance of X in midparent-offspring regression is the sum of the variances of the two parents shown in Equation 3 assuming the variability of the two parents are equal (Hallauer and Miranda, 1988).

$$\text{Eqn. 2:} \quad \overline{X} = \frac{X_1 + X_2}{2}$$

$$= (1/2)X_1 + (1/2)X_2.$$

$$\text{Eqn. 3:} \quad \sigma_X^2 = (1/4)\sigma_{X_1}^2 + (1/4)\sigma_{X_2}^2 = (1/2)\sigma_X^2.$$

Covariance of Midparent-Offspring Derivation

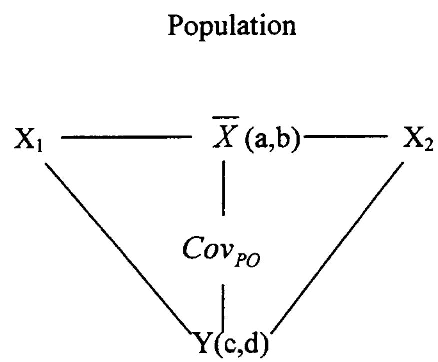

Figure 1. Diagram of midparent-offspring covariance derivation modified from Hallauer (2002).

The covariance of the midparent-offspring relationship is $(1/2)\sigma_A^2$ as derived below. The regression equation then becomes a measure of the narrow-sense heritability as shown in Equation 4 because there is only additive variance in the numerator.

$$\text{Eqn. 4:} \quad b = \frac{(1/2)\sigma_A^2}{(1/2)\sigma_X^2} = \frac{\sigma_A^2}{\sigma_X^2}.$$

To derive the covariance of midparent-offspring (Figure 1), assume a population from which two individuals (X_1 and X_2) are randomly selected. Individuals X_1 and X_2 have two alleles at a specific locus (a,b) and (c,d) respectively. $\overline{X}$ is the average of parents X_1 and X_2 giving the midparent value. The covariance of midparent-offspring is the same as the covariance of the parent-offspring relationship. The probability of allele "c" being identical to allele "a" is ½ and the probability that allele "c" is identical to allele "b" is ½. The probability that allele "c" is identical to "a" or "b" (Φ) is shown in Equation 5.

$$\text{Eqn. 5:} \quad \Phi = P(c = a) + P(c = b)$$
$$= 1/2 + 1/2 = 1.$$

Malécot (1948) derived a general equation to describe the covariance of relatives in terms of additive genetic and dominance variance components shown in Equation 6.

$$\text{Eqn. 6: } Cov = \left(\frac{\Phi + \Phi'}{2}\right)\sigma_A^2 + (\Phi\Phi')\sigma_D^2 .$$

In midparent-offspring regression, Φ' is not a component of the covariance because there is only one set of offspring. If there were two sets of offspring, as in full-sibs, Φ' could be computed. Using Malécot's (1948) equation, the covariance of midparent-offspring becomes $(1/2)\sigma_A^2$ assuming no epistasis (Equation 7). The general formula for the covariance of midparent-offspring relation is given in Equation 8, where F is the coefficient of inbreeding of the parents.

$$\text{Eqn. 7: } Cov_{MPO} = \left(\frac{1+0}{2}\right)\sigma_A^2 + (1)(0)\sigma_D^2 = (1/2)\sigma_A^2 .$$

$$\text{Eqn. 8: } Cov_{MPO} = \left(\frac{1+F}{2}\right)\sigma_A^2 .$$

The covariance of the midparent-offspring relation including digenic additive epistasis is shown in Equation 9. There is no dominance variance, which is the reason midparent-offspring regression is a measure of narrow-sense heritability.

$$\text{Eqn. 9: } Cov_{MPO} = (1/2)\sigma_A^2 + (1/4)\sigma_{AA}^2 .$$

If the data are unbalanced, the analysis is not as simple. Kempthorne and Tandon (1953) reported two methods of weighting data to alleviate this problem. The first repeats the parental record with each offspring record. This is the correct method if the correlation among the progeny of a parent is zero. The second method averages all offspring of a parent and regresses that value on the correct parental record. This method is appropriate if the correlation among offspring is one. The real value of correlation often lies between zero and one making neither method perfect. Bohren and McKean (1961) suggest little difference between the two methods given by Kempthorne and Tandon (1953). Falconer and Mackay (1996) suggest weighting has negligible influence if large numbers of families are included.

Midparent-Offspring Heritability Estimation From Least Squares Regression

Midparent-offspring regression has several advantages over other types of heritability estimates. The association between parents and offspring can often be readily identified in the field. The heritability estimate is based on least squares regression where the calculations are well studied. Dominance and linkage do not affect the covariance between parent and offspring. The estimate remains unbiased by selection of parents (Kempthorne and Tandon, 1953; Lush, 1994; Lynch and Walsh, 1998).

Depending on the relationship of individuals involved, two types of heritability estimates are available from regression. The estimate of $h^2=2b_1$ is appropriate in cross-fertilizing species when half-sib offspring are regressed on one parental value and b_1 represents the regression coefficient. The other estimate of heritability from regression is $h^2=b_1$. This estimate is appropriate in cross-fertilizing species when full-sib progeny are regressed on the midparent value, as in this study, or in self-fertilizing species when F_1/F_2 or F_2/F_3 combinations are used. If the parents are inbred or related and the covariance is not adjusted, heritability will be overestimated (Smith and Kinman, 1965; Fernandez and Miller, 1985; Hallauer and Miranda, 1988).

In maize [*Zea mays* L.], parent-offspring regression can be used to determine three estimates of heritability depending on the relationship of individuals in the study. The three types of estimates are (1) regression of selfed progeny on parents (2) regression of half-sibs on one parental value and (3) regression of full-sib progeny on midparent value (Hallauer and Miranda, 1988). This study used method (3) of estimating heritability.

Midparent-offspring regression more accurately estimates heritability than parent-offspring regression. It directly estimates heritability so any errors in the estimate are not multiplied by two inflating the estimate (Lush, 1994). When the midparent value is used in calculations, a 30 to 40% gain in precision of the estimate over single-parent regression is realized (Latter and Robertson, 1960; Lynch and Walsh, 1998).

Midparent-Offspring Regression Assumptions

Various authors have outlined the assumptions to accurately measure heritability using midparent-offspring regression (Cockerham, 1963; Vogel *et al.*, 1980; Fernandez and Miller, 1985; Falconer and Mackay, 1996; Lynch and Walsh, 1998). Failure of any of these assumptions could lead to a biased estimate. These assumptions include:

1. regular diploid Mendelian inheritance;
2. random mating population;
3. no environmental correlations among relatives;
4. relatives noninbred;
5. negligible dominance and epistatic effects; and
6. parents measured without error.

One of the assumptions for covariances between relatives is that no linkage exists. Linkage does not affect midparent-offspring regression if the population is random mating (Cockerham, 1956; Cockerham, 1963; Nyquist, 1991), but linkage must still be acknowledged as a potential source of bias (Cockerham, 1956).

The assumption of no environmental correlation, while frequently violated, contends that all genotype-by-environment covariances between parents and progenies are zero (Vogel *et al.*, 1980; Casler 1982). This occurs when parents and progeny are not grown in independent environments. The resulting heritability estimate includes more than the additive genetic variance in the numerator; it also contains the genotype-by-environment covariance. Often, the covariances are positive resulting in an inflated estimate of heritability.

Several methods of removing genotype-by-environment bias from the heritability estimate have been proposed. Dudley *et al.* (1969) suggested estimating and removing the applicable covariances from the numerator of the heritability estimate. This works well with perennial species where the parents and progeny may be included in the same environment. Vogel *et al.* (1980) suggested regressing progeny means from one environment on parental means from an independent environment. With two independent environments there can be no genotype-by-environment interaction to bias the heritability estimate. Care must be taken that differential environmental expression on parents and progeny does not exist. Frey and

Horner (1957) proposed standardizing the phenotypic variances of the parent and offspring to adjust for these scale effects; however, the phenotypic variances of the parent and offspring must be equal except for the scaling factor, which is rarely true. Another way to remove genotype-by-environment covariance from the heritability estimate is to regrow a second sample of the random mating population in the same environment as the offspring. The regression coefficient could then be adjusted by multiplying it by the ratio of phenotypic standard deviation of the first parental sample to the phenotypic standard deviation of the second parental sample grown in the offspring environment (Nyquist, 1991).

An upward bias in the heritability estimate results with inbred parents (Cockerham, 1963; Hanson, 1963; Smith and Kinman, 1965; Nyquist, 1991; Gibson, 1996), which may result in heritability estimates greater than one (Kelly and Bliss, 1975). Failure to correct for inbreeding can be especially severe in self-fertilized crops. Smith and Kinman (1965) proposed a correction for inbreeding of the parents based on the theory that parental alleles at a specific locus of an inbred plant could be identical by descent (Malécot, 1948) giving a nonzero coefficient of inbreeding. Following this idea, the heritability estimate then becomes $h^2 = b_1 / 2r_{XY}$ where r_{XY} is Malécot's (1948) coefficient of relation. In general when the parent, Y is partially inbred $r_{XY} = (1/2)(1 + F_Y)$ where F_Y is the coefficient of inbreeding. Hanson (1963), Nyquist (1991), and Gibson (1996) have modified the Smith and Kinman (1965) estimate into $b' = b / [1 + F_t (1 - b)]$ where b' equals the strict narrow-sense heritability, b represents the regression coefficient, and F_t represents the inbreeding coefficient of the generation of line derivation.

Nonadditive effects such as epistasis may result in a bias in the heritability estimate because the Cov_{MPO} term contains not only the additive genetic variance but also portions of the epistatic variance (Casler, 1982; Gibson, 1996). Depending on the amount of additional factors in the numerator heritability may be overestimated or underestimated. However, Gibson (1996) demonstrated that when gene frequencies approach equilibrium ($p=q=½$), as in a random mating population, the effect of epistasis on the heritability estimate becomes small. Epistasis should be acknowledged as a potential source of bias in estimating heritability.

One of the major assumptions of midparent-offspring regression is that the true regression is linear. Plots of midparent and offspring phenotypes often appear linear which may be explained statistically by the central limit theorem. The central limit theorem states that the sum of a number of independent random variables approaches normality as the number of variables increases. This is often assumed in quantitative genetics if the environment and a number of unlinked genes with small additive effects influence a trait (Lynch and Walsh, 1998).

Bulmer (1976), Robertson (1977), Gimelfarb (1986), and Choo (1989) presented papers on the assumption of linearity. Bulmer (1976) concluded mathematically that in the absence of linkage, parent-offspring regression is linear but the residual variance is affected if linkage is present. Robertson (1977) found regression of progeny means on parental phenotypes might not be linear due to nonadditive gene action and/or environmental effects in *Drosophila*. Gimelfarb (1986) mathematically showed for purely additive loci, dominance would not cause nonlinearity unless the trait is strongly influenced by a few recessive alleles. Choo (1989), working with barley [*Hordeum vulgare* L.], was the first to report experimental evidence in plants regarding the linearity of midparent-offspring regression. Choo (1989) determined midparent-offspring regression is linear even though previous studies indicated dominance, additive-by-additive epistasis, and maternal effects were present in the population studied.

Midparent-Offspring Correlation

Midparent-offspring correlation is another method of illustrating the degree of relation for specific traits between parents and offspring. Midparent-offspring correlation may be calculated as $Cov_{MPO} / \sigma_O \sigma_{MP}$ when σ_O and σ_{MP} are the square root of the phenotypic variances of the offspring and midparent respectively. From this equation it can be noted that the number of offspring and the number of parents can affect the correlation making the interpretation of results difficult. If only one offspring is correlated with one parent, the results should approximate the regression of offspring on parent. When one offspring is correlated with the midparent value, the correlation becomes $b_{MPO} / \sqrt{2}$. If more than one offspring is measured the correlation coefficient depends on the family size and the heritability estimate itself making interpretation of the results difficult (Lush, 1994; Falconer and Mackay, 1996; Lynch and Walsh, 1998).

Midparent-offspring correlation gives the same relative ranking of traits as heritability estimates; i.e., traits with higher heritability estimates have higher correlation coefficients. Uhr and Murphy (1992) in oats [*Avena sativa* L.], Glover and Scott (1998) working with soybean [*Glycine max* L.], and Smalley (2000) in maize [*Zea mays* L.] found that traits with higher heritability estimates have higher correlation coefficients when properly corrected for inbreeding.

Inheritance of Traits Investigated

Yield, plant height, ear height, and tassel branch number are complex traits governed by quantitative inheritance. Estimates of heritability reported for all traits vary according to the population and type of heritability estimate reported. In general, plant height, ear height, and tassel branch number have higher heritabilities than yield. These results follow the theory that traits highly correlated with reproduction, such as yield, have lower heritability estimates than traits with lower correlation to reproduction (Falconer and Mackay, 1996).

The estimates of heritability for specific traits vary depending on the population studied, the experimental unit used in calculation, the types of relatives measured, and the environmental conditions. The standard errors or confidence intervals reported should also be examined. Several studies have been conducted in maize to calculate heritability for plant height, ear height, tassel branch number, and yield components with variable results (Table 1). Robinson *et al.* (1949) regressed half-sib offspring on one parent to obtain combined heritability estimates of three single crosses for plant height, ear height, and yield. The female-offspring regression heritabilities are reported in Table 1. Mock and Schuetz (1974) estimated heritability for tassel branch number over two years on a single plant basis with variance components and using F_2/F_3 regression. The combined heritability estimates are reported in Table 1. The combined heritability estimate for both years is reported in Table 1. Berke and Rocheford (1999) reported heritability estimates for tassel branch number on a single plant basis. Smalley (2000) regressed half-sib S_1 lines on female

Table 1. Heritability estimates for different traits of maize under study reported in literature.

Trait†	Author	h^2 Type‡	h^2 Estimate	Standard Error	CI (90%)
PH	Robinson *et al.* (1949)	P-O Reg	0.42	0.04	
	Berke & Rocheford (1995)	Family Mean	0.84		(0.80, 0.87)
	Smalley (2000)	P-O Reg	0.56	0.06	
EH	Robinson *et al.* (1949)	P-O Reg	0.41	0.05	
	Berke & Rocheford (1995)	Family Mean	0.80		(0.75, 0.84)
	Smalley (2000)	P-O Reg	0.51	0.05	
TBN	Mock & Schuetz (1974)	F_2/F_3 Reg	0.38	0.04	
	Smalley (2000)	P-O Reg	0.61	0.05	
YD	Robinson *et al.* (1949)	P-O Reg	0.10	0.04	
	Smalley (2000)	P-O Reg	0.07	0.02	

† PH = plant height, EH = ear height, TBN = tassel branch number, YD = yield.
‡ h^2 = heritability, P-O Reg = parent-offspring regression, F_2/F_3 Reg = F_2/F_3 regression.
Family mean and single plant heritability estimates obtained from components of variance.

parent to obtain heritability estimates for plant height, ear height, tassel branch number, and yield in the BS10 and BS11 populations. The combined estimate of BS10 and BS11 over environments is reported in Table 1.

MATERIALS AND METHODS

Genetic Materials

BS10, previously designated Iowa Two Ear Synthetic, was developed by W. A. Russell *et al.* (1971) by intermating 10 two-eared Corn Belt Dent lines: R71, ITE701, HD2158, HD2244, HD2418, B58, B60, (N32xB14)B14-1-30-4, (Oh43xB33)-139, and Krug-792. The population was developed to provide a genetically broad-based population with two ears and good combining ability.

BS11, previously designated Pioneer Two-ear Composite, was developed by W. L. Brown by intermating southern prolific material, Caribbean material, and Corn Belt lines (Hallauer, 1967).

Reciprocal full-sib recurrent selection has been practiced between these two populations as described by Hallauer (1973) for 15 cycles. Materials for this study were derived from cycle 14.

Field Methods

During the summer of 2000, 25 rows each of BS10 and BS11 were planted in paired rows. All rows were machine planted 4.57 m long with a 0.90 m alley preceding the beginning of the next row. The rows were spaced 0.76 m apart. Twenty-five kernels were planted per row and thinned at approximately the V6 stage (Ritchie *et al.,* 1993) to 15 plants to promote prolificacy.

Full-sib crosses were made between paired S_0 plants in adjacent rows (BS10 x BS11) producing S_0 x S_0 full-sib seed on the primary ears. The secondary ear of each parental S_0 plant was self-pollinated to produce S_1 seed for intermating the next cycle. Plants were used as parents once.

At approximately the R3 stage, plant height, ear height, and tassel branch number were measured on each parental S_0 plant. Plant height was measured as the height, in centimeters, of the node of the flag leaf from the soil surface. Ear height was measured as the height, in centimeters, of the node of the primary ear shank from the soil surface. Tassel branch number was measured as the number of primary tassel branches at least 2.54 cm long protruding from the main spike.

During the fall of 2000, all ears from each parental S_0 plant were harvested by hand and the identity of full-sib and S_1 ears were maintained. The ears were dried for three days at 100^0C to a moisture level of 15%. The ears were shelled and the grain yield measured as the total amount of grain (primary, secondary, and any additional ears) in g plant^{-1}. The primary, secondary, and any additional ears of each plant were kept separate. All ears except the primary and secondary ears were discarded. After the yield data were collected, the full-sib families (S_0 x S_0 crosses) were bulked, assigned an arbitrary entry number, and placed into cold storage for the winter.

During the spring of 2001, 209 entries and 16 checks were machine planted in a 15 x 15 lattice at four Iowa environments (Ames, Ankeny, Lewis, and Crawfordsville). Two replications were planted at each environment. The plots were two rows 4.57 m long with a 0.90 m alley preceding the beginning of the next row and 0.76 m between rows.

All plots were thinned at approximately the V6 stage of development to an even stand of 56 plants per plot (67,000 plants ha^{-1}). Stand counts were taken during the thinning process.

At approximately the R3 stage, plant height, ear height, and tassel branch number were measured on 10 competitive plants in each plot growing in Ames and Lewis, IA in the same manner the parents were measured. Competitive plants were defined as healthy plants with competitive plants adjacent within the row and in adjoining rows. The 10 measurements from each plot were averaged to obtain a mean for the plot used in regression calculations.

Plots were machine harvested at maturity at all four environments. Yields were taken on a weight basis and adjusted for moisture and stand counts. Yields were then converted to g plant^{-1}.

Statistical Methods

Full-sib covariance derivation: Heritability estimates using full-sib families are broad-sense estimates because some of the dominance variance is in the numerator. The derivation of the covariance of full-sib families is shown in Figure 2.

The covariance of relatives is a measure of the commonality of alleles. To derive the covariance of full-sibs assume a population from which two individuals (A and B) are randomly selected. Individuals A and B have two alleles at a specific locus (a,b) and (c,d), respectively. The probability of allele "a" being identical to allele "g" is ½ and the probability that allele "a" is the same as allele "e" is ½. The probability that allele "e" is identical to allele "g" (Φ) is the sum of the probability that allele "a" is the same as alleles "e" and "g" plus the probability that allele "b" is the same as alleles "e" and "g". This is

Covariance of Full-Sibs Derivation

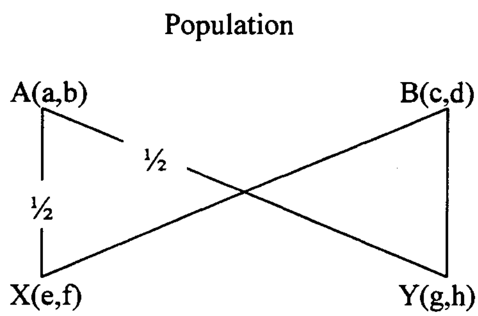

Figure 2. Diagram of full-sib covariance derivation modified from Hallauer (2002).

shown in Equation 10. The probability that allele "f" is identical to allele "h" (Φ') is determined following the same logic as shown in Equation 11.

$$\text{Eqn. 10: } \Phi = P(e = g) = [P(a = e = g) + P(b = e = g)]$$
$$= (1/2)(1/2) + (1/2)(1/2)$$
$$= 1/4 \quad + \quad 1/4 \quad = 1/2.$$

$$\text{Eqn. 11: } \Phi' = P(f = h) = [P(c = f = h) + P(d = f = h)]$$
$$= (1/2)(1/2) + (1/2)(1/2)$$
$$= 1/4 \quad + \quad 1/4 \quad = 1/2.$$

Malécot (1948) derived the equation for the covariance of relatives in terms of the additive genetic and dominance variance components (Equation 12).

$$\text{Eqn. 12} \quad Cov_{FS} = \left(\frac{\Phi + \Phi'}{2}\right)\sigma_A^2 + (\Phi\Phi')\sigma_D^2.$$

Substituting in the values for Φ and Φ', the covariance of full-sib families becomes $(1/2)\sigma_A^2 + (1/4)\sigma_D^2$ (Equation 13), assuming no inbreeding and no epistasis. The general formula for the covariance of full-sib families is shown in Equation 14 where F is the inbreeding coefficient of the parents (Hallauer and Miranda, 1988).

$$\text{Eqn. 13:} \quad Cov_{FS} = \left(\frac{(1/2)+(1/2)}{2}\right)\sigma_A^2 + (1/2)(1/2)\sigma_D^2.$$

The coefficients for the epistatic components of variance are found by multiplying the appropriate σ_A^2 and σ_D^2 coefficients. The covariance of full-sib families including digenic epistasis is shown in Equation 15.

$$\text{Eqn. 14:} \quad Cov_{FS} = \left(\frac{1+F}{2}\right)\sigma_A^2 + \left(\frac{1+F}{2}\right)^2 \sigma_D^2.$$

$$\text{Eqn. 15:} \quad Cov_{FS} = (1/2)\sigma_A^2 + (1/4)\sigma_D^2 + (1/4)\sigma_{AA}^2 + (1/8)\sigma_{AD}^2 + (1/16)\sigma_{DD}^2.$$

The broad-sense heritability estimate (h_b^2) on a full-sib family basis is the ratio of the genotypic variance, shown in Equation 15, to the phenotypic variance (Equation 16). Epistatic interactions have been left out for simplicity and the lack of a direct estimate should be acknowledged. Because estimates of σ_A^2 and σ_D^2 cannot be obtained from the data for this study, the heritability estimate becomes Equation 17 where the components of variance are obtained from analysis of variance.

$$\text{Eqn. 16:} \quad h^2 = \frac{(1/2)\sigma_A^2 + (1/4)\sigma_D^2}{\sigma^2 + (1/2)\sigma_{AE}^2 + (1/4)\sigma_{DE}^2 + (1/2)\sigma_A^2 + (1/4)_D^2}.$$

$$\text{Eqn. 17:} \quad h^2 = \frac{\sigma_G^2}{\sigma_G^2 + \sigma_{GE}^2 + \sigma_e^2}.$$

Heritability from midparent-offspring regression: The family means were obtained for each replication at each environment by averaging the 10 measurements taken on each plot. The family means of each environment were the adjusted for any intrablock effects using Proc Mixed in the Statistical Analysis Software (SAS) (SAS Institute Inc., 1999) and are included in Appendix A. Family means of each trait were combined across environments using Proc Mixed in SAS. The family means across all environments are included in Appendix B.

Midparent-offspring regression analysis was preformed with the adjusted progeny means using Proc Reg in SAS. The model used was $Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i$. The midparent value, given in Appendix C, was the independent variable and the progeny mean was the dependent variable. Regression analysis was done for each trait at each environment and each trait combined over environments. The residual versus predicted plots were constructed for each regression. All regression graphs are included in Appendix D. The materials were noninbred (F=0) so no adjustment for inbreeding was necessary. Points more than two and a half standard deviations from the mean were deleted. These included entries 12, 27, and 51 at Lewis for ear height. Heritability estimates were obtained from β_1. Confidence intervals of the heritability estimates were calculated using Equation 18.

$$\text{Eqn. 18:} \quad CI = \beta_1 \pm t_{(1-\alpha/2)} s_j .$$

Nonlinearity of the model was tested using the lack-of-fit (LOF) procedure outlined by Steel *et al.* (1997) and Draper and Smith (1966). The model was considered nonlinear when LOF p-value ≥ 0.05. If evidence of LOF existed, higher order models were not fitted (Bulmer, 1976; Choo, 1989).

Full-sib family heritability estimation across environments using lattice design: The adjusted overall mean for each entry was analyzed using Proc GLM to obtain variance components for heritability estimates. The expected mean squares, combined across environments, for the experiment are shown in Table 2. Replications/environments and blocks/replications/environments are listed to show all the degrees of freedom. Replications/environments and blocks/replications/environments were left out of the expected mean squares because the individual environments were analyzed using Proc Mixed in SAS, which adjusts the means based on the replication and block effects. This is also why replications are not included in Equations 16 and 17. Genotypes were broken down into families, checks, and the orthogonal comparison of families versus checks. All terms were tested using the corresponding interaction with environments. Checks and families

Table 2. Analysis of variance table with sources of variation, degrees of freedom (df), mean squares (MS), and expected mean squares across four environments.

Sources of variation	df		MS	Expected mean squares
Environments (E)	(e-1)	3		$\sigma_e^2 + \sigma_{GE}^2 + g\sigma_E^2$
Replications/environments	(r-1)e	3		
Blocks/replications/ environments	(b-1)re	112		
Genotypes (G)	(g-1)	224	MS_3	$\sigma_e^2 + \sigma_{GE}^2 + e\sigma_G^2$
S_0 Families (F)	(f-1)	208	MS_{31}	$\sigma_e^2 + \sigma_{FE}^2 + e\sigma_F^2$
Checks (C)	(c-1)	15	MS_{32}	$\sigma_e^2 + \sigma_{CE}^2 + e\Phi_C$
F vs C	1	1	MS_{33}	$\sigma_e^2 + \sigma_{(FvsC)E}^2 + e\sigma_{(FvsC)}^2$
Genotype x environment	(g-1)(e-1)	672	MS_2	$\sigma_e^2 + \sigma_{GE}^2$
F x E	(f-1)(e-1)	624	MS_{21}	$\sigma_e^2 + \sigma_{FE}^2$
C x E	(c-1)(e-1)	45	MS_{22}	$\sigma_e^2 + \sigma_{CE}^2$
(F vs C) x E	(e-1)(1)	3	MS_{23}	$\sigma_e^2 + \sigma_{(FvsC)E}^2$
Pooled Error	e[{(r-1)(g-1)}-{(b-1)r}]	785	MS_1	σ_e^2
Total	erg-1	1799		

were divided to obtain the broad-sense heritability on an entry-mean basis of the families only. The pooled error term was used to test the genotype-by-environment and family-by-environment interactions as well as the (family versus check)-by-environment interaction. The environment term was tested by the genotype-by-environment interaction.

The pooled error term was constructed from the effective error mean squares (EEMS) obtained from the Proc Mixed procedure in SAS. The EEMS term is calculated from the sum of the standard error of the difference of every mean comparison possible divided by the number of replications. The EEMS is the number of replications multiplied by the variance of the difference between two means and that quantity divided by two (Equation 19).

$$\text{Eqn. 19:} \quad EEMS = \frac{(r)\sum[Var(Diff)]}{2}.$$

The EEMS were obtained for each trait at each environment. To obtain the pooled error term over environments, the EEMS for each environment was multiplied by the number of degrees of freedom associated with it giving the effective error sums of squares for each environment. These sums of squares were summed over environments for each trait and the total sums of squares divided by the sum of degrees of freedom over environments to obtain the pooled error term.

Knapp *et al.* (1985) rewrote Equation 17into Equation 20 which is the equation used to estimate broad-sense heritability in this study for the S_0 families where σ_G^2 is the genotypic variance, σ_{GE}^2 is the genotype by environment variance, and σ_e^2 is the environmental variance. MS_{21} and MS_{31} are from Table 2.

$$\text{Eqn. 17:} \quad h^2 = \frac{\sigma_G^2}{\sigma_G^2 + \sigma_{GE}^2 + \sigma_e^2}.$$

$$\text{Eqn. 20:} \quad h^2 = 1 - \left(\frac{MS_{21}}{MS_{31}}\right).$$

The corresponding 95% confidence intervals were computed by the method outlined by Knapp *et al.* (1985):

$$\text{Eqn. 21:} \quad UCL = 1 - \{(R)(F_{0.975:df31,df21})\}^{-1}; \text{ and}$$

$$\text{Eqn. 22:} \quad LCL = 1 - \{(R)(F_{0.025:df31,df21})\}^{-1},$$

where UCL is the upper confidence limit and LCL is the lower confidence limit. R is the F-statistic to test the null hypothesis that the genetic variance is zero (MS_{21} / MS_{31}).

Full-sib family heritability at individual environments using RCBD: Lattice designs are resolvable incomplete block designs meaning they can be analyzed as a randomized complete block design (RCBD); however, the ability to adjust means based on intrablock effects is lost decreasing the precision of the estimates. Randomized complete block analysis does allow for variance component analysis at individual environments allowing heritability estimates to be computed at individual environments. The expected mean squares for one trait at one environment are shown in Table 3. The analysis was completed using Proc GLM in SAS. S_0 families were tested with the error term. Heritability estimates for each trait at each environment were computed using Equation 23 (Knapp *et al.* 1985). MS_1 and MS_2 were obtained from Table 3.

Table 3. Analysis of variance table with sources of variation, degrees of freedom (df), mean squares (MS), and expected mean squares for one trait at one environment.

Sources of variation	df		MS	Expected mean squares
Replications	(r-1)	1		$\sigma_e^2 + g\sigma_r^2$
S_0 Families (F)	(f-1)	208	MS_2	$\sigma_e^2 + r\sigma_g^2$
Error	(r-1)(f-1)	208	MS_1	σ_e^2
Total	rf-1	417		

Eqn. 23: $h^2 = 1 - \left(\frac{MS_1}{MS_2}\right).$

Correlation analysis: Phenotypic correlations between traits were computed for Ames, Lewis, and the combined means using Proc Corr in SAS (Appendix G). Midparent-offspring correlations were computed were also computed using Proc Corr. Correlations were calculated by $r_{X/Y} = Cov_{MPO} / \sigma_O \sigma_{MP}$ where σ_O and σ_{MP} are the square root of the phenotypic variances of the offspring and midparent value. Correlations were significant when $p \leq 0.05$. Significance was determined by Student's t-distribution, n-2 degrees of freedom, using Equation 24 where n is the total number of means used in the computations and r is the appropriate correlation.

Eqn. 24 : $\frac{(n-2)^{1/2} r}{(1-r^2)^{1/2}}.$

RESULTS AND DISCUSSION

Normality Distributions

To examine whether parents were randomly sampled, the Anderson-Darling test for normality was performed on the parental data (Draper and Smith, 1966; Lorenzen and Anderson, 1993) using Proc Univariate in SAS. Evidence for non-normality existed when $P \leq 0.05$. The BS11 population had evidence of non-normality for tassel branch number (P=0.018). All other traits of interest where nonsignificant ($P \geq 0.05$) so the assumption of random sampling generally holds true. Draper and Smith (1966) and Steel *et al.* (1997) suggest regression is fairly robust to slight deviations from normality. Kempthorne and Tandon (1953), Lush (1994), and Lynch and Walsh (1998) suggested the heritability estimate remains unbiased by selection of parents.

Midparent-Offspring Regression

Linearity of regression: There was evidence of nonlinearity for yield at Ankeny but it was weak (P=0.048). Residual versus predicted plots were constructed for each regression. The residual plots all appeared as horizontal bands with random distribution of points indicating no abnormality and no trends were revealed (Draper and Smith, 1966). The distributions of points around the regression line also were normal.

Heritability estimates from regression: Heritability estimates for all traits of interest were found directly from the regression coefficient. Heritability estimates and corresponding confidence intervals are given in Table 4 for each trait at every environment and the combined heritability estimate across environments.

Plant height had consistent heritability estimates across environments as shown in Table 4. The combined heritability estimate was 0.419 (0.365, 0.474). This estimate was the same as plant height heritability using parent-offspring regression previously reported by Robinson *et al.* (1949) as 0.42 ± 0.04. It was lower than the heritability estimate reported by Smalley (2000) as 0.56 ± 0.06. Smalley (2000) measured half-sib families in one-row plots at two environments so the estimate cannot be directly compared with the plant height heritability estimate of this study. All three studies indicate gain in selection for plant height could be accomplished.

Tassel branch number showed consistent heritability estimates at both Ames and Lewis. The combined heritability estimate was 0.340 (0.270, 0.410). Berke and Rocheford (1995) estimated heritability of tassel branch number to be 0.90 with a corresponding 90% confidence interval of (0.87, 0.92). This heritability estimate was obtained using parent-offspring regression and doubling the resulting regression coefficient. Smalley (2000) reported tassel branch heritability to be 0.61 ± 0.05. While neither study can be directly compared with this study, tassel branch number is a trait with relatively higher heritability. This indicates gain from selection for the number of tassel branches is possible.

A discrepancy did arise in the heritability estimates for ear height, which was 0.391 (0.334, 0.449) at Ames and 0.053 (-0.027, 0.134) at Lewis. This could be because the parents were grown and measured in Ames so environmental correlation may exist, which could upwardly bias the results at that environment. However, ear height heritability using parent-offspring regression has been reported to be higher than 0.053. Robinson *et al.* (1949) found ear height to have a heritability of 0.41 ± 0.05 and Smalley (2000) estimated ear height heritability to be 0.51 ± 0.05.

Heritability estimates for yield varied from –0.018 at Crawfordsville to 0.057 at Ames but the confidence intervals overlapped. The heritability estimate combined across environments was 0.009. These heritability estimates were lower than those reported by Robinson *et al.* (1949) and Smalley (2000) who reported 0.10 ± 0.04 and 0.07 ± 0.02, respectively. Heritability estimates for yield in all studies were the lowest of any trait reported. All studies indicate that selection for yield may be possible but realized progress would be slower than for traits such as plant height, ear height, and tassel branch number.

Table 4. Heritability estimates from midparent-offspring regression analysis at four environments for yield and at two environments for plant and ear height and tassel branch number in maize.

	b_1 and corresponding confidence interval (95%)			
Environment	Yield	Plant height	Ear height	Tassel branch no.
	g plant^{-1}	(cm)	(cm)	
Ames	0.057 (-0.002, 0.115)	0.428 (0.369, 0.487)	0.391 (0.334, 0.449)	0.353 (0.275, 0.431)
Lewis	-0.005 (-0.064, 0.054)	0.400 (0.345, 0.456)	0.053 (-0.027, 0.134)	0.327 (0.256, 0.398)
Ankeny	0.004 (-0.085, 0.089)			
Crawfordsville	-0.018 (-0.089, 0.052)			
Combined	0.009 (-0.034, 0.052)	0.419 (0.365, 0.474)	0.079 (0.035, 0.155)	0.340 (0.270, 0.410)

Full-sib family heritability estimation across environments

Full-sib family heritability estimates from components of variance were computed to compare with the heritability estimates obtained from midparent-offspring regression. The family means adjusted for intrablock effects were used. The mean squares and corresponding significance levels are displayed in Appendix E. The heritability estimates are given in Table 5. For each trait, the heritabilities from the components of variance are higher than those from midparent-offspring regression. This is due to midparent-offspring regression measuring narrow-sense heritability while the full-sib family heritability is in the broad sense. Also, components of variance heritabilities are a ratio of the covariance of full-sibs to the phenotypic variance of full-sib families while midparent-offspring regression is a ratio of the midparent-offspring covariance to the midparent phenotypic variance. Yield and ear height showed higher full-sib heritability estimates than those obtained from midparent-offspring regression. The trend noted by Smalley (2000) and Robinson *et al.* (1949) of plant and ear height having similar heritabilities is noted in the components of variance heritability estimates.

Table 5. Heritability estimates combined across environments for midparent-offspring regression and components of variance for four traits in maize.

	Midparent-offspring regression		Components of variance	
Trait	Heritability	Confidence interval (95%)	Heritability	Confidence interval (95%)
Yield (g plant^{-1})	0.009	(-0.034, 0.052)	0.404	(0.260, 0.526)
Plant height (cm)	0.419	(0.365, 0.474)	0.651	(0.542, 0.734)
Ear height (cm)	0.079	(0.035, 0.155)	0.639	(0.526, 0.725)
Tassel branch no.	0.340	(0.270, 0.410)	0.450	(0.278, 0.581)

Full-sib family heritability at individual environments

Broad-sense heritability estimates for each trait at individual environments were computed using unadjusted means. The mean squares used to calculate the heritability estimates are included in Appendix F. The estimates and confidence intervals for each estimate are given in Table 6. The heritability estimates from the components of variance were higher than the heritability estimates from midparent-offspring regression in all cases. This is because midparent-offspring regression is a measure of narrow-sense heritability and the components of variance is a measure of broad-sense heritability. Also, unadjusted means were used in the components of variance heritability estimates, which decrease the precision of the estimate. Traits with low influence on reproductive fitness, such as plant height, ear height, and tassel branch number, showed higher heritabilities than yield. The heritability estimate of yield at Ames was lower than that of the other environments. This demonstrates the effect environment can have on the phenotype and the need for replication at different environments to obtain more precise estimates. Ear height heritabilities from the components of variance analysis were stable across environments 0.776 (0.705, 0.829) at Ames and 0.806 (0.743, 0.852) at Lewis compared with variable ear height heritabilities obtained from midparent-offspring regression of 0.391 (0.334, 0.449) at Ames and 0.053 (-0.027, 0.134) at Lewis (Table 4). This demonstrates the upward environmental bias associated with the midparent-offspring regression ear height heritability at Ames.

Correlation analysis

Midparent-offspring correlations were performed for each trait. The offspring were correlated with the midparent for all traits at Ames but for plant height and tassel branch number only at Lewis. This may be due to the environmental correlation that exists because the parents were grown in Ames but not in Lewis. When the combined offspring means across environments were correlated with the midparent, significance was detected for plant height and tassel branch number only. Traits with higher heritability estimates, regardless of the method used to estimate heritability, were traits with higher correlation between the midparent and offspring. Midparent-offspring correlations are shown in Table 7.

Table 6. Heritability estimates calculated from components of variance at four environments for yield and two environments for plant and ear height, and tassel branch number in maize.

	h^2 and corresponding confidence interval (95%)			
Environment	Yield g $plant^{-1}$	Plant height (cm)	Ear height (cm)	Tassel branch no.
Ames	0.192 (-0.059, 0.386)	0.744 (0.663, 0.804)	0.776 (0.705, 0.829)	0.850 (0.803, 0.885)
Lewis	0.405 (0.215, 0.548)	0.826 (0.770, 0.867)	0.806 (0.743, 0.852)	0.798 (0.733, 0.846)
Ankeny	0.500 (0.343, 0.619)			
Crawfordsville	0.424 (0.245, 0.562)			

Table 7. Phenotypic correlations of midparent and offspring in maize at two locations with four environments for yield and two environments for plant and ear height and tassel branch no. in the combined correlation.

	Trait			
Environment	Yield	Plant height	Ear height	Tassel branch no.
	(g $plant^{-1}$)	(cm)	(cm)	
Ames	0.132*	0.703**	0.636**	0.526**
Lewis	-0.012^{ns}	0.688**	0.058^{ns}	0.535**
Combined	0.029^{ns}	0.729**	0.065^{ns}	0.556**

*, ** significant at 0.05 and 0.01 levels, respectively
ns, nonsignificant

Phenotypic trait correlations were performed for Ames, Lewis, and the combined data over environments (Appendix G). In all cases, plant height was positively correlated ($P \leq 0.01$) with ear height and tassel branch number. Ear height was also positively correlated ($P \leq 0.01$) with tassel branch number. Yield was not significantly correlated with any trait. Selection for plant height would not result in higher yielding plants but could result in plants with adjusted ear height and tassel branch number.

CONCLUSIONS

Heritability estimates for the same trait in the same population vary depending on the type of heritability computed. Midparent-offspring regression is a measure of narrow-sense heritability and is not inflated by nonadditive components of variance, such as dominance. Several assumptions must be met to correctly interpret the results from midparent-offspring regression. All assumptions were met for this study with the exception of no environmental correlation. The parents were grown and measured in Ames and the full-sib families were also grown and measured in Ames, which gave upwardly biased heritability estimates for Ames. This could be seen in the comparison of ear height heritabilities between Ames 0.391 (0.334, 0.449) and Lewis 0.053 (-0.027, 0.134). However, the heritability estimates from the components of variance were 0.776 (0.705, 0.829) at Ames and 0.806 (0.743, 0.852) at Lewis. The components of variance heritability estimates did not take midparent data into account and therefore were not biased by environmental correlations and remained constant across environments.

Traits with higher midparent-offspring heritability estimates also had higher midparent-offspring correlations. The exception was ear height, which was highly correlated at Ames (0.636) but was not significantly correlated at Lewis (0.058). Again, environmental correlation may have upwardly biased the Ames correlations.

Based on the heritabilities obtained in this study from midparent-offspring regression, selection for plant height and tassel branch number would make progress more quickly than selection for yield and ear height. Selection for plant height and tassel branch number could be done with less extensive testing than yield and ear height which showed a greater environmental influence. Individual plant selection such as mass selection may be effective for plant height and tassel branch number. Yield and ear height selection would be better on a progeny mean basis across multiple environments. Based on the results from this experiment, individual plant selection for yield and ear height would not be an effective method of selection.

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APPENDIX A

MEANS OF GENOTYPES AT INDIVIDUAL ENVIRONMENTS FOR EACH TRAIT

Table A1. Plot mean performance of all offspring genotypes grown at Ames, IA, 2001.

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
1	2891-07/2892-07	104.8	207	107	19
2	2891-06/2892-12	97.6	196	91	15
3	2891-02/2892-11	103.0	200	100	17
4	2891-08/2892-08	105.9	216	112	18
5	2891-10/2892-05	122.5	212	106	12
6	2891-05/2892-02	100.8	206	102	14
7	2891-01/2892-01	105.5	201	100	18
8	2891-04/2892-03	126.1	217	102	14
9	2891-15/2892-10	108.4	214	109	15
10	2891-03/2892-14	107.7	212	103	16
11	2891-14/2892-13	97.8	239	117	15
12	2893-11/2894-13	100.4	189	87	18
13	2893-07/2894-08	108.0	203	103	16
14	2893-04/2894-18	105.3	215	104	24
15	2893-03/2894-03	103.0	221	109	15
16	2893-06/2894-05	93.6	202	103	13
17	2893-02/2894-16	111.4	218	114	13
18	2893-10/2894-12	100.7	208	106	14
19	2895-15/2896-09	80.6	207	108	17
20	2895-13/2896-03	90.1	202	92	13
21	2895-10/2896-14	90.6	213	104	14
22	2895-01/2896-01	128.0	217	105	15
23	2895-03/2896-06	112.5	240	119	15
24	2895-14/2896-15	120.1	212	98	14
25	2895-04/2896-04	113.9	197	92	12
26	2895-11/2896-08	97.3	194	91	15
27	2895-08/2896-02	120.3	198	91	18
28	2897-06/2898-11	95.7	195	96	15
29	2897-11/2898-04	103.6	216	105	13
30	2897-13/2898-13	103.1	210	108	19
31	2897-10/2898-08	95.1	206	98	17
32	2897-01/2898-02	100.2	207	107	16

† Pedigrees abbreviated. The BS11 plant is listed first and the BS10 after /.
‡ Height measured from soil surface to flag leaf node.
§ Height measured from soil surface to upper ear shank node.
¶ Number of primary tassel branches attached to main spike.

Table A1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
33	2897-08/2898-07	112.0	190	95	17
34	2897-09/2898-12	93.7	207	108	19
35	2899-02/2900-01	83.8	186	85	15
36	2899-14/2900-11	102.2	213	98	15
37	2899-04/2900-05	98.0	194	94	15
38	2899-11/2900-12	113.8	205	104	14
39	2899-06/2900-06	86.3	197	98	19
40	2899-13/2900-08	115.9	203	97	11
41	2899-01/2900-02	108.6	220	121	16
42	2899-07/2900-10	114.4	219	112	16
43	2901-12/2902-06	96.6	219	110	20
44	2901-16/2902-12	124.4	194	100	18
45	2901-15/2902-04	102.8	208	107	18
46	2901-02/2902-07	100.0	221	115	15
47	2901-08/2902-11	118.9	195	98	18
48	2901-01/2902-02	99.7	207	102	15
49	2901-09/2902-10	92.9	215	104	18
50	2901-10/2902-01	112.7	213	102	13
51	2903-16/2904-05	97.9	239	131	23
52	2903-02/2904-14	83.3	194	84	16
53	2903-01/2904-01	120.3	207	101	15
54	2903-14/2904-08	114.0	212	107	13
55	2903-15/2904-16	98.2	210	114	18
56	2905-01/2906-02	102.9	211	104	16
57	2905-12/2906-12	101.6	212	107	17
58	2905-04/2908-03	109.5	207	101	17
59	2905-15/2906-16	124.0	206	102	14
60	2905-10/2906-07	101.7	203	101	14
61	2905-02/2906-05	106.8	210	102	19
62	2905-08/2906-09	109.3	193	94	16
63	2905-17/2906-15	89.3	195	91	14
64	2905-05/2906-03	107.2	214	108	17

Table A1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
69	2907-06/2908-06	96.4	217	105	15
70	2907-10/2908-14	107.5	219	123	18
71	2907-14/2908-16	117.6	206	107	16
72	2907-02/2908-02	84.7	207	107	18
73	2909-12/2910-16	107.5	224	116	19
74	2909-13/2910-02	100.0	219	103	16
75	2909-04/2910-05	109.7	224	114	16
76	2909-01/2910-03	98.1	205	114	16
77	2909-11/2910-10	85.9	206	101	25
78	2909-02/2910-04	108.2	222	113	17
79	2911-08/2912-14	110.5	210	105	17
80	2911-13/2912-15	100.6	218	100	17
81	2911-03/2912-05	122.6	214	102	12
82	2911-12/2912-12	105.9	207	108	18
83	2911-14/2912-16	98.2	225	114	14
84	2911-09/2912-10	101.4	208	95	17
85	2911-04/2912-06	136.0	189	89	15
86	2913-05/2914-02	114.4	226	115	18
87	2913-07/2914-07	105.3	215	115	23
88	2913-13/2914-18	119.0	195	96	13
89	2913-11/2914-17	85.7	193	96	14
90	2913-19/2914-08	106.0	212	105	18
91	2913-03/2914-01	98.0	199	100	17
92	2913-01/2914-05	111.1	219	100	13
93	2915-11/2916-11	74.4	211	111	16
94	2915-07/2916-08	126.4	235	124	17
95	2915-14/2916-14	84.1	203	94	14
96	2915-04/2916-05	116.0	218	105	14
97	2915-02/2916-02	102.6	216	110	15
98	2915-01/2916-15	111.1	197	89	14
99	2915-13/2916-16	90.6	198	94	14
100	2915-12/2916-09	124.4	223	115	16
101	2917-09/2918-02	126.7	202	101	14
102	2917-08/2918-14	109.8	211	105	17
103	2917-11/2918-11	88.9	218	113	15
104	2917-03/2918-01	109.3	210	107	13

Table A1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
105	2917-13/2918-16	103.3	209	113	15
106	2917-02/2918-03	114.6	217	109	19
107	2917-18/2918-15	106.0	231	120	15
108	2919-11/2920-14	95.2	209	113	20
109	2919-17/2920-16	98.4	191	92	14
110	2919-15/2920-15	86.7	214	109	12
111	2919-04/2920-12	103.0	213	107	14
112	2921-02/2922-01	112.0	205	104	13
113	2921-01/2922-04	104.1	202	100	12
114	2921-13/2922-16	101.4	210	107	16
115	2921-11/2922-14	115.9	202	105	17
116	2921-09/2922-12	115.6	206	96	10
117	2921-14/2922-17	106.4	205	107	18
118	2921-07/2922-13	104.0	206	106	14
119	2921-10/2922-08	100.4	215	102	15
120	2921-15/2922-03	114.8	180	82	15
121	2921-03/2922-02	109.5	206	106	15
122	2921-04/2922-05	113.9	228	114	15
123	2923-14/2924-02	105.7	222	114	14
124	2923-05/2924-10	80.7	203	100	17
125	2923-01/2924-01	112.0	213	111	12
126	2923-11/2924-11	89.7	200	105	14
127	2923-15/2924-07	98.8	218	114	17
128	2923-07/2924-15	94.8	215	119	20
129	2923-04/2924-09	104.5	189	87	14
130	2923-03/2924-03	100.1	200	91	15
131	2925-03/2924-17	98.3	221	120	22
132	2923-10/2924-04	97.3	229	110	13
133	2925-04/2926-07	102.0	214	105	14
134	2925-01/2926-01	103.1	198	108	16
135	2925-09/2926-05	93.8	209	109	15
136	2925-06/2926-03	97.5	200	99	19
137	2925-14/2926-12	70.2	202	95	10
138	2925-12/2926-11	102.9	212	102	13
139	2925-13/2926-04	108.4	222	111	13
140	2925-08/2926-08	105.1	207	111	19

Table A1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
141	2925-02/2926-06	98.8	213	107	19
142	2925-15/2926-14	107.1	220	108	13
143	2927-17/2928-09	96.8	190	92	14
144	2927-02/2928-02	107.7	215	113	13
145	2927-05/2928-13	124.7	211	107	18
146	2927-01/2928-03	95.1	196	93	16
147	2927-03/2928-05	106.3	194	90	19
148	2927-07/2928-07	109.8	206	112	16
149	2927-06/2928-04	108.6	213	111	17
150	2929-08/2930-10	110.2	201	94	11
151	2929-03/2930-12	112.2	199	92	14
152	2929-10/2930-01	112.3	214	100	14
153	2929-12/2930-03	91.7	222	123	18
154	2929-14/2930-07	96.3	220	103	17
155	2931-08/2932-02	124.2	218	113	14
156	2931-15/2932-14	112.0	215	107	14
157	2931-01/2932-17	108.9	208	106	17
158	2931-12/2932-01	112.4	216	101	13
159	2933-12/2934-17	113.2	205	108	11
160	2933-04/2934-05	108.9	215	108	17
161	2933-07/2934-15	113.6	209	102	13
162	2933-13/2934-14	96.7	201	99	17
163	2933-14/2934-16	94.6	216	108	14
164	2934-10/2935-17	106.3	210	102	24
165	2933-02/2934-01	119.8	217	104	14
166	2933-15/2934-02	106.1	208	98	17
167	2935-03/2936-06	111.1	215	105	10
168	2935-15/2936-08	86.1	211	107	14
169	2935-05/2936-10	118.8	233	113	14
170	2935-01/2936-05	122.8	216	109	13
171	2935-04/2936-14	92.3	208	104	16
172	2935-16/2936-13	107.2	217	108	18
173	2937-13 /2938-03	95.1	203	95	13
174	2937-04/2938-07	120.2	217	109	13
175	2937-02/2938-12	89.1	221	116	17
176	2937-08/2938-04	106.0	212	112	16

Table A1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
177	2937-03/2938-06	101.8	218	109	18
178	2937-14/2938-01	114.7	207	105	19
179	2937-01/2938-02	93.4	203	101	15
180	2939-12/2940-12	100.1	215	113	18
181	2939-02/2940-04	96.3	202	108	17
182	2939-01/2940-03	99.8	224	116	16
183	2939-08/2940-11	126.7	216	108	12
184	2939-16/2940-14	111.4	199	100	15
185	2939-11/2940-15	111.4	223	102	15
186	2939-14/2940-10	112.8	219	113	17
187	2941-13/2942-04	91.1	217	110	19
188	2941-15/2942-15	97.2	213	97	16
189	2941-05/2942-05	94.6	203	97	16
190	2943-15/2944-16	101.4	209	108	17
191	2943-14/2944-14	111.8	211	102	15
192	2943-05/2944-10	116.8	211	101	18
193	2945-01/2946-01	108.3	206	99	13
194	2945-17/2946-10	100.3	219	108	12
195	2945-03/2946-03	95.4	205	103	12
196	2945-05/2946-02	126.5	211	105	13
197	2945-06/2946-07	110.6	225	106	17
198	2947-03/2948-05	120.3	209	100	14
199	2947-15/2948-13	110.4	213	106	16
200	2947-02/2948-02	94.4	176	81	13
201	2947-06/2948-04	91.7	206	107	17
202	2947-14/2948-15	108.5	215	104	19
203	2947-10/2948-16	102.1	214	100	17
204	2949-09/2950-16	95.5	208	104	16
205	2949-13/2950-15	103.0	217	117	12
206	2949-04/2950-04	103.8	208	105	10
207	2949-01/2950-02	106.4	196	92	14
208	2949-05/2950-05	83.1	190	93	11
209	2949-08/2950-17	115.5	209	102	14
210	B45/CI31A	75.6	206	108	14
211	B37/Oh43	83.5	187	78	10
212	B14/B45	83.3	200	92	9

Table A1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
213	AES704	64.0	194	90	11
214	IA5115	73.8	214	107	13
215	IA5116	79.1	198	96	13
216	BS10C0	65.9	194	99	19
217	BS11C0	88.7	210	117	23
218	BS10/BS11)C0	86.8	209	111	19
219	BS10(FR)C14	100.5	213	102	13
220	BS11(FR)C14	84.3	207	97	14
221	DK595	128.8	211	87	7
222	DK611	139.5	200	98	9
223	DK5738	127.4	192	100	9
224	RX730	141.4	204	96	7
225	P33G26	146.0	219	104	7
	Exp Mean#	104.1	209	104	15
	Min Mean††	64.0	176	78	7
	Max Mean‡‡	146.0	240	131	25
	$LSD_{0.05}$§§	28.2	13	10	3
	EEMS¶¶	199.2	42	27	2

Experimental mean.
†† Minimum mean.
‡‡ Maximum mean.
§§ Least significant difference at 0.05 probability level.
¶¶ Effective error mean squares.

Table A2. Plot mean performance of all offspring genotypes grown at Lewis, IA, 2001.

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
1	2891-07/2892-07	65.9	203	104	16
2	2891-06/2892-12	58.5	219	108	11
3	2891-02/2892-11	62.4	210	108	14
4	2891-08/2892-08	80.9	229	122	13
5	2891-10/2892-05	81.8	214	117	10
6	2891-05/2892-02	69.8	219	111	11
7	2891-01/2892-01	57.5	204	99	13
8	2891-04/2892-03	92.0	225	116	14
9	2891-15/2892-10	62.3	215	111	12
10	2891-03/2892-14	78.6	236	126	14
11	2891-14/2892-13	65.3	242	124	10
12	2893-11/2894-13	68.3	193	88	14
13	2893-07/2894-08	58.7	215	119	13
14	2893-04/2894-18	62.2	223	115	20
15	2893-03/2894-03	78.1	237	125	12
16	2893-06/2894-05	70.0	218	116	10
17	2893-02/2894-16	88.8	226	118	11
18	2893-10/2894-12	70.0	210	111	12
19	2895-15/2896-09	61.6	219	122	13
20	2895-13/2896-03	63.0	222	112	10
21	2895-10/2896-14	69.3	226	119	14
22	2895-01/2896-01	82.9	224	116	13
23	2895-03/2896-06	53.8	242	127	12
24	2895-14/2896-15	75.7	222	113	10
25	2895-04/2896-04	78.8	215	113	10
26	2895-11/2896-08	78.9	204	99	13
27	2895-08/2896-02	67.1	203	95	15
28	2897-06/2898-11	55.2	214	113	14
29	2897-11/2898-04	78.6	233	121	11
30	2897-13/2898-13	77.5	224	115	14
31	2897-10/2898-08	74.8	217	113	13
32	2897-01/2898-02	72.4	223	124	15

† Pedigrees abbreviated. The BS11 plant is listed first and the BS10 after /.
‡ Height measured from soil surface to flag leaf node.
§ Height measured from soil surface to upper ear shank node.
¶ Number of primary tassel branches attached to main spike.

Table A2. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
33	2897-08/2898-07	68.7	209	105	14
34	2897-09/2898-12	63.8	227	129	16
35	2899-02/2900-01	77.8	201	100	11
36	2899-14/2900-11	70.9	224	114	12
37	2899-04/2900-05	82.3	215	110	12
38	2899-11/2900-12	63.3	225	122	11
39	2899-06/2900-06	63.5	215	117	14
40	2899-13/2900-08	69.4	214	113	9
41	2899-01/2900-02	58.3	231	134	13
42	2899-07/2900-10	55.7	234	135	13
43	2901-12/2902-06	63.3	238	126	14
44	2901-16/2902-12	84.2	206	117	13
45	2901-15/2902-04	56.0	208	107	15
46	2901-02/2902-07	72.2	229	120	12
47	2901-08/2902-11	63.0	207	109	16
48	2901-01/2902-02	66.1	216	113	13
49	2901-09/2902-10	80.4	223	119	17
50	2901-10/2902-01	69.4	221	114	10
51	2903-16/2904-05	48.4	244	145	17
52	2903-02/2904-14	55.1	208	99	12
53	2903-01/2904-01	73.3	207	107	12
54	2903-14/2904-08	68.7	217	114	11
55	2903-15/2904-16	65.7	229	131	12
56	2905-01/2906-02	66.0	237	128	13
57	2905-12/2906-12	80.5	219	112	16
58	2905-04/2908-03	75.9	215	114	13
59	2905-15/2906-16	74.1	214	118	12
60	2905-10/2906-07	65.9	217	119	12
61	2905-02/2906-05	77.9	226	118	14
62	2905-08/2906-09	68.5	207	110	14
63	2905-17/2906-15	82.7	208	94	10
64	2905-05/2906-03	64.6	222	116	14
65	2905-16/2906-01	55.0	228	120	12
66	2907-01/2908-01	62.2	208	103	14
67	2907-04/2908-07	82.3	209	102	11
68	2907-09/2908-10	63.7	218	114	11

Table A2. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
69	2907-06/2908-06	86.7	228	108	11
70	2907-10/2908-14	71.8	221	126	15
71	2907-14/2908-16	63.0	216	122	14
72	2907-02/2908-02	69.9	218	113	15
73	2909-12/2910-16	73.6	239	132	15
74	2909-13/2910-02	49.5	228	113	12
75	2909-04/2910-05	77.6	239	127	13
76	2909-01/2910-03	53.3	203	121	14
77	2909-11/2910-10	58.0	221	120	16
78	2909-02/2910-04	69.2	233	118	14
79	2911-08/2912-14	71.9	233	126	14
80	2911-13/2912-15	34.9	226	114	13
81	2911-03/2912-05	64.3	225	108	9
82	2911-12/2912-12	64.1	219	118	16
83	2911-14/2912-16	82.4	232	122	11
84	2911-09/2912-10	105.6	221	113	13
85	2911-04/2912-06	62.4	205	111	13
86	2913-05/2914-02	76.1	241	128	13
87	2913-07/2914-07	60.2	234	137	20
88	2913-13/2914-18	73.0	218	120	12
89	2913-11/2914-17	75.2	205	114	12
90	2913-19/2914-08	69.3	221	118	14
91	2913-03/2914-01	73.7	224	118	16
92	2913-01/2914-05	83.4	230	116	11
93	2915-11/2916-11	64.1	224	125	13
94	2915-07/2916-08	70.5	233	126	13
95	2915-14/2916-14	76.3	215	106	11
96	2915-04/2916-05	72.1	231	127	10
97	2915-02/2916-02	55.1	224	124	12
98	2915-01/2916-15	66.4	217	102	10
99	2915-13/2916-16	54.1	207	104	12
100	2915-12/2916-09	#	#	#	#
101	2917-09/2918-02	72.1	225	119	13
102	2917-08/2918-14	64.6	222	122	14
103	2917-11/2918-11	59.5	228	121	14
104	2917-03/2918-01	64.7	213	112	9

Table A2. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
105	2917-13/2918-16	80.5	221	124	11
106	2917-02/2918-03	75.3	224	125	17
107	2917-18/2918-15	44.5	242	135	10
108	2919-11/2920-14	65.4	221	122	16
109	2919-17/2920-16	53.4	192	98	12
110	2919-15/2920-15	78.6	225	123	10
111	2919-04/2920-12	59.9	223	119	10
112	2921-02/2922-01	82.4	222	114	9
113	2921-01/2922-04	75.1	218	114	10
114	2921-13/2922-16	67.6	213	116	13
115	2921-11/2922-14	52.5	215	119	14
116	2921-09/2922-12	78.1	214	109	9
117	2921-14/2922-17	77.6	224	123	13
118	2921-07/2922-13	70.1	220	121	13
119	2921-10/2922-08	60.1	224	118	13
120	2921-15/2922-03	72.0	202	103	12
121	2921-03/2922-02	64.3	214	115	14
122	2921-04/2922-05	32.1	234	130	11
123	2923-14/2924-02	80.6	232	124	13
124	2923-05/2924-10	68.8	219	111	12
125	2923-01/2924-01	80.1	217	114	8
126	2923-11/2924-11	78.4	211	116	11
127	2923-15/2924-07	59.1	231	135	16
128	2923-07/2924-15	52.1	226	132	16
129	2923-04/2924-09	79.5	217	109	12
130	2923-03/2924-03	64.3	213	111	10
131	2925-03/2924-17	78.6	235	136	18
132	2923-10/2924-04	75.0	244	127	9
133	2925-04/2926-07	70.9	228	120	13
134	2925-01/2926-01	62.7	208	116	14
135	2925-09/2926-05	72.2	222	121	12
136	2925-06/2926-03	75.4	211	111	15
137	2925-14/2926-12	81.4	214	108	8
138	2925-12/2926-11	74.8	233	126	12
139	2925-13/2926-04	76.5	231	123	12
140	2925-08/2926-08	78.3	216	122	14

Table A2. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
141	2925-02/2926-06	69.3	224	120	17
142	2925-15/2926-14	79.1	230	123	10
143	2927-17/2928-09	77.2	203	107	13
144	2927-02/2928-02	74.2	208	113	11
145	2927-05/2928-13	65.5	223	118	14
146	2927-01/2928-03	79.0	200	99	16
147	2927-03/2928-05	65.0	214	106	18
148	2927-07/2928-07	71.2	219	124	13
149	2927-06/2928-04	69.2	220	119	12
150	2929-08/2930-10	67.2	217	111	8
151	2929-03/2930-12	67.3	202	99	15
152	2929-10/2930-01	66.2	230	118	12
153	2929-12/2930-03	#	#	#	#
154	2929-14/2930-07	86.3	244	119	11
155	2931-08/2932-02	62.4	229	121	11
156	2931-15/2932-14	76.9	217	119	12
157	2931-01/2932-17	68.1	225	123	15
158	2931-12/2932-01	84.9	221	106	10
159	2933-12/2934-17	#	#	#	#
160	2933-04/2934-05	79.8	237	128	14
161	2933-07/2934-15	53.2	214	115	12
162	2933-13/2934-14	69.5	214	113	14
163	2933-14/2934-16	63.8	228	120	12
164	2934-10/2935-17	63.4	229	119	19
165	2933-02/2934-01	77.8	236	122	11
166	2933-15/2934-02	51.2	229	126	12
167	2935-03/2936-06	86.7	221	117	5
168	2935-15/2936-08	57.9	224	124	13
169	2935-05/2936-10	77.2	235	123	11
170	2935-01/2936-05	77.5	213	120	11
171	2935-04/2936-14	74.2	221	122	14
172	2935-16/2936-13	74.9	221	111	16
173	2937-13 /2938-03	72.4	215	105	12
174	2937-04/2938-07	88.6	234	131	13
175	2937-02/2938-12	60.6	232	125	13
176	2937-08/2938-04	81.0	219	117	12

Table A2. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
177	2937-03/2938-06	77.1	236	131	16
178	2937-14/2938-01	80.2	220	121	17
179	2937-01/2938-02	48.8	203	107	12
180	2939-12/2940-12	73.4	226	125	15
181	2939-02/2940-04	57.6	222	126	14
182	2939-01/2940-03	50.6	229	128	15
183	2939-08/2940-11	89.7	222	117	11
184	2939-16/2940-14	76.4	214	114	11
185	2939-11/2940-15	62.6	234	116	13
186	2939-14/2940-10	86.5	228	120	14
187	2941-13/2942-04	66.2	238	120	14
188	2941-15/2942-15	58.3	231	110	15
189	2941-05/2942-05	46.6	219	120	14
190	2943-15/2944-16	66.8	218	114	14
191	2943-14/2944-14	65.3	219	111	11
192	2943-05/2944-10	71.5	221	118	14
193	2945-01/2946-01	73.6	210	103	13
194	2945-17/2946-10	73.6	227	119	10
195	2945-03/2946-03	76.6	212	112	10
196	2945-05/2946-02	58.2	222	113	12
197	2945-06/2946-07	76.0	236	122	14
198	2947-03/2948-05	63.8	229	122	12
199	2947-15/2948-13	59.3	231	123	11
200	2947-02/2948-02	66.7	196	96	11
201	2947-06/2948-04	77.9	230	127	15
202	2947-14/2948-15	64.4	220	119	23
203	2947-10/2948-16	80.1	218	108	11
204	2949-09/2950-16	56.6	225	122	14
205	2949-13/2950-15	66.5	216	116	9
206	2949-04/2950-04	74.1	215	114	10
207	2949-01/2950-02	59.1	208	106	12
208	2949-05/2950-05	63.8	198	105	7
209	2949-08/2950-17	81.9	224	122	10
210	B45/CI31A	60.8	230	123	10
211	B37/Oh43	39.6	201	77	8
212	B14/B45	48.2	220	108	8

Table A2. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
213	AES704	47.1	210	98	9
214	IA5115	42.2	220	114	11
215	IA5116	43.0	213	111	10
216	BS10C0	32.3	207	108	14
217	BS11C0	24.8	219	125	17
218	BS10/BS11)C0	47.4	210	108	15
219	BS10(FR)C14	60.5	223	110	11
220	BS11(FR)C14	56.4	230	113	10
221	DK595	115.1	209	92	6
222	DK611	108.8	211	108	7
223	DK5738	105.4	205	92	8
224	RX730	107.1	206	89	6
225	P33G26	97.8	214	102	5
	Exp Mean††	69.1	221	116	13
	Min Mean‡‡	24.8	192	77	5
	Max Mean§§	115.1	244	145	23
	$LSD_{0.05}$¶¶	21.7	11	11	3
	EEMS##	117.6	33	29	2

†† Experimental mean.
‡‡ Minimum mean.
§§ Maximum mean.
¶¶ Least significant difference at 0.05 probability level.
Effective error mean squares used to calculate pooled error term.

Table A3. Plot mean performance of all offspring genotypes grown at Ankeny, IA, 2001.

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
1	2891-07/2892-07	127.7	34	2897-09/2898-12	93.9
2	2891-06/2892-12	120.5	35	2899-02/2900-01	105.5
3	2891-02/2892-11	142.5	36	2899-14/2900-11	101.4
4	2891-08/2892-08	117.8	37	2899-04/2900-05	127.4
5	2891-10/2892-05	147.6	38	2899-11/2900-12	113.1
6	2891-05/2892-02	99.3	39	2899-06/2900-06	121.1
7	2891-01/2892-01	114.1	40	2899-13/2900-08	107.4
8	2891-04/2892-03	132.8	41	2899-01/2900-02	115.7
9	2891-15/2892-10	128.2	42	2899-07/2900-10	131.6
10	2891-03/2892-14	112.0	43	2901-12/2902-06	107.2
11	2891-14/2892-13	121.0	44	2901-16/2902-12	122.9
12	2893-11/2894-13	130.0	45	2901-15/2902-04	128.3
13	2893-07/2894-08	131.9	46	2901-02/2902-07	126.6
14	2893-04/2894-18	119.2	47	2901-08/2902-11	113.9
15	2893-03/2894-03	123.7	48	2901-01/2902-02	123.0
16	2893-06/2894-05	124.4	49	2901-09/2902-10	109.3
17	2893-02/2894-16	126.5	50	2901-10/2902-01	152.2
18	2893-10/2894-12	123.4	51	2903-16/2904-05	75.4
19	2895-15/2896-09	81.0	52	2903-02/2904-14	106.6
20	2895-13/2896-03	52.5	53	2903-01/2904-01	103.9
21	2895-10/2896-14	125.8	54	2903-14/2904-08	115.2
22	2895-01/2896-01	126.3	55	2903-15/2904-16	114.1
23	2895-03/2896-06	134.5	56	2905-01/2906-02	97.1
24	2895-14/2896-15	93.4	57	2905-12/2906-12	108.7
25	2895-04/2896-04	135.5	58	2905-04/2908-03	143.4
26	2895-11/2896-08	120.0	59	2905-15/2906-16	114.7
27	2895-08/2896-02	108.3	60	2905-10/2906-07	135.7
28	2897-06/2898-11	106.8	61	2905-02/2906-05	127.9
29	2897-11/2898-04	126.9	62	2905-08/2906-09	115.3
30	2897-13/2898-13	115.1	63	2905-17/2906-15	99.7
31	2897-10/2898-08	124.6	64	2905-05/2906-03	107.7
32	2897-01/2898-02	129.7	65	2905-16/2906-01	112.1
33	2897-08/2898-07	100.6	66	2907-01/2908-01	131.0

† Pedigrees abbreviated. The BS11 plant is listed first and the BS10 after /.

Table A3. (Cont.)

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
67	2907-04/2908-07	113.2	103	2917-11/2918-11	104.9
68	2907-09/2908-10	120.5	104	2917-03/2918-01	130.7
69	2907-06/2908-06	129.5	105	2917-13/2918-16	140.0
70	2907-10/2908-14	138.4	106	2917-02/2918-03	137.7
71	2907-14/2908-16	124.2	107	2917-18/2918-15	115.0
72	2907-02/2908-02	101.7	108	2919-11/2920-14	104.9
73	2909-12/2910-16	130.9	109	2919-17/2920-16	109.1
74	2909-13/2910-02	128.2	110	2919-15/2920-15	131.0
75	2909-04/2910-05	132.2	111	2919-04/2920-12	102.1
76	2909-01/2910-03	119.5	112	2921-02/2922-01	134.9
77	2909-11/2910-10	112.1	113	2921-01/2922-04	106.6
78	2909-02/2910-04	87.2	114	2921-13/2922-16	131.7
79	2911-08/2912-14	138.5	115	2921-11/2922-14	123.4
80	2911-13/2912-15	134.9	116	2921-09/2922-12	136.3
81	2911-03/2912-05	140.0	117	2921-14/2922-17	126.3
82	2911-12/2912-12	141.3	118	2921-07/2922-13	95.8
83	2911-14/2912-16	125.5	119	2921-10/2922-08	97.6
84	2911-09/2912-10	112.1	120	2921-15/2922-03	105.5
85	2911-04/2912-06	109.4	121	2921-03/2922-02	111.1
86	2913-05/2914-02	123.7	122	2921-04/2922-05	110.9
87	2913-07/2914-07	121.8	123	2923-14/2924-02	84.2
88	2913-13/2914-18	115.9	124	2923-05/2924-10	105.1
89	2913-11/2914-17	118.6	125	2923-01/2924-01	122.6
90	2913-19/2914-08	117.8	126	2923-11/2924-11	105.6
91	2913-03/2914-01	100.3	127	2923-15/2924-07	130.3
92	2913-01/2914-05	120.2	128	2923-07/2924-15	102.3
93	2915-11/2916-11	120.1	129	2923-04/2924-09	88.3
94	2915-07/2916-08	127.3	130	2923-03/2924-03	116.1
95	2915-14/2916-14	102.1	131	2925-03/2924-17	118.7
96	2915-04/2916-05	128.0	132	2923-10/2924-04	123.3
97	2915-02/2916-02	127.6	133	2925-04/2926-07	120.1
98	2915-01/2916-15	103.7	134	2925-01/2926-01	121.7
99	2915-13/2916-16	126.4	135	2925-09/2926-05	118.4
100	2915-12/2916-09	129.0	136	2925-06/2926-03	124.3
101	2917-09/2918-02	152.2	137	2925-14/2926-12	105.2
102	2917-08/2918-14	98.2	138	2925-12/2926-11	123.8

Table A3. (Cont.)

Entry No.	Pedigree†	Yield (g plant^{-1})	Entry No.	Pedigree†	Yield (g plant^{-1})
139	2925-13/2926-04	119.8	175	2937-02/2938-12	79.7
140	2925-08/2926-08	100.8	176	2937-08/2938-04	126.3
141	2925-02/2926-06	147.6	177	2937-03/2938-06	150.6
142	2925-15/2926-14	142.9	178	2937-14/2938-01	107.2
143	2927-17/2928-09	123.7	179	2937-01/2938-02	96.3
144	2927-02/2928-02	115.1	180	2939-12/2940-12	110.3
145	2927-05/2928-13	146.3	181	2939-02/2940-04	108.6
146	2927-01/2928-03	116.3	182	2939-01/2940-03	135.1
147	2927-03/2928-05	121.8	183	2939-08/2940-11	101.2
148	2927-07/2928-07	134.5	184	2939-16/2940-14	103.9
149	2927-06/2928-04	120.6	185	2939-11/2940-15	131.8
150	2929-08/2930-10	125.0	186	2939-14/2940-10	152.4
151	2929-03/2930-12	122.3	187	2941-13/2942-04	120.2
152	2929-10/2930-01	137.6	188	2941-15/2942-15	131.6
153	2929-12/2930-03	88.4	189	2941-05/2942-05	83.8
154	2929-14/2930-07	116.0	190	2943-15/2944-16	127.0
155	2931-08/2932-02	139.9	191	2943-14/2944-14	117.9
156	2931-15/2932-14	145.7	192	2943-05/2944-10	107.6
157	2931-01/2932-17	107.8	193	2945-01/2946-01	136.2
158	2931-12/2932-01	116.7	194	2945-17/2946-10	106.9
159	2933-12/2934-17	161.5	195	2945-03/2946-03	142.1
160	2933-04/2934-05	138.8	196	2945-05/2946-02	108.5
161	2933-07/2934-15	109.2	197	2945-06/2946-07	121.7
162	2933-13/2934-14	135.4	198	2947-03/2948-05	121.8
163	2933-14/2934-16	145.8	199	2947-15/2948-13	105.9
164	2934-10/2935-17	97.2	200	2947-02/2948-02	109.6
165	2933-02/2934-01	132.6	201	2947-06/2948-04	121.6
166	2933-15/2934-02	137.2	202	2947-14/2948-15	115.4
167	2935-03/2936-06	96.6	203	2947-10/2948-16	136.7
168	2935-15/2936-08	95.2	204	2949-09/2950-16	113.4
169	2935-05/2936-10	135.9	205	2949-13/2950-15	140.0
170	2935-01/2936-05	108.2	206	2949-04/2950-04	141.0
171	2935-04/2936-14	125.3	207	2949-01/2950-02	131.7
172	2935-16/2936-13	119.5	208	2949-05/2950-05	118.5
173	2937-13 /2938-03	119.8	209	2949-08/2950-17	112.1
174	2937-04/2938-07	152.2	210	B45/CI31A	94.3

Table A3. (Cont.)

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
211	B37/Oh43	91.5	219	BS10(FR)C14	98.7
212	B14/B45	63.5	220	BS11(FR)C14	102.9
213	AES704	47.0	221	DK595	165.1
214	IA5115	73.8	222	DK611	177.6
215	IA5116	47.5	223	DK5738	144.0
216	BS10C0	60.0	224	RX730	139.4
217	BS11C0	47.2	225	P33G26	182.0
218	BS10/BS11)C0	69.0			
	Exp Mean‡	118.0			
	Min Mean§	47.0			
	Max Mean¶	182.0			
	$LSD_{0.05}$#	31.8			
	EEMS††	252.3			

‡ Experimental mean.
§ Minimum mean.
¶ Maximum mean.
# Least significant difference at 0.05 probability level.
†† Effective error mean squares used to calculate pooled error term.

Table A4. Plot mean performance of all offspring genotypes grown at Crawfordsville, IA, 2001.

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
1	2891-07/2892-07	137.7	34	2897-09/2898-12	136.0
2	2891-06/2892-12	137.0	35	2899-02/2900-01	145.6
3	2891-02/2892-11	148.5	36	2899-14/2900-11	128.4
4	2891-08/2892-08	150.8	37	2899-04/2900-05	125.4
5	2891-10/2892-05	154.3	38	2899-11/2900-12	137.7
6	2891-05/2892-02	141.2	39	2899-06/2900-06	157.2
7	2891-01/2892-01	151.1	40	2899-13/2900-08	133.9
8	2891-04/2892-03	156.4	41	2899-01/2900-02	159.8
9	2891-15/2892-10	140.3	42	2899-07/2900-10	154.6
10	2891-03/2892-14	150.2	43	2901-12/2902-06	161.2
11	2891-14/2892-13	138.5	44	2901-16/2902-12	147.0
12	2893-11/2894-13	144.3	45	2901-15/2902-04	149.7
13	2893-07/2894-08	132.2	46	2901-02/2902-07	141.3
14	2893-04/2894-18	150.9	47	2901-08/2902-11	123.0
15	2893-03/2894-03	164.3	48	2901-01/2902-02	142.5
16	2893-06/2894-05	132.2	49	2901-09/2902-10	142.8
17	2893-02/2894-16	165.6	50	2901-10/2902-01	136.4
18	2893-10/2894-12	156.2	51	2903-16/2904-05	132.2
19	2895-15/2896-09	139.0	52	2903-02/2904-14	134.4
20	2895-13/2896-03	159.1	53	2903-01/2904-01	144.1
21	2895-10/2896-14	128.5	54	2903-14/2904-08	136.4
22	2895-01/2896-01	126.2	55	2903-15/2904-16	157.7
23	2895-03/2896-06	139.9	56	2905-01/2906-02	149.7
24	2895-14/2896-15	147.7	57	2905-12/2906-12	132.1
25	2895-04/2896-04	167.4	58	2905-04/2908-03	108.6
26	2895-11/2896-08	137.3	59	2905-15/2906-16	143.8
27	2895-08/2896-02	114.3	60	2905-10/2906-07	135.4
28	2897-06/2898-11	138.3	61	2905-02/2906-05	158.0
29	2897-11/2898-04	161.8	62	2905-08/2906-09	141.9
30	2897-13/2898-13	128.8	63	2905-17/2906-15	134.7
31	2897-10/2898-08	141.8	64	2905-05/2906-03	132.9
32	2897-01/2898-02	139.4	65	2905-16/2906-01	124.5
33	2897-08/2898-07	148.8	66	2907-01/2908-01	138.2

† Pedigrees abbreviated. The BS11 plant is listed first and the BS10 after /.

Table A4. (Cont.)

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
67	2907-04/2908-07	123.0	103	2917-11/2918-11	122.1
68	2907-09/2908-10	128.9	104	2917-03/2918-01	135.6
69	2907-06/2908-06	153.0	105	2917-13/2918-16	138.3
70	2907-10/2908-14	148.4	106	2917-02/2918-03	149.8
71	2907-14/2908-16	121.2	107	2917-18/2918-15	147.0
72	2907-02/2908-02	122.7	108	2919-11/2920-14	114.0
73	2909-12/2910-16	156.2	109	2919-17/2920-16	105.8
74	2909-13/2910-02	131.3	110	2919-15/2920-15	135.9
75	2909-04/2910-05	156.8	111	2919-04/2920-12	142.8
76	2909-01/2910-03	132.3	112	2921-02/2922-01	143.9
77	2909-11/2910-10	138.7	113	2921-01/2922-04	142.5
78	2909-02/2910-04	130.9	114	2921-13/2922-16	130.5
79	2911-08/2912-14	143.5	115	2921-11/2922-14	148.1
80	2911-13/2912-15	164.6	116	2921-09/2922-12	163.5
81	2911-03/2912-05	138.0	117	2921-14/2922-17	152.6
82	2911-12/2912-12	133.0	118	2921-07/2922-13	132.3
83	2911-14/2912-16	127.7	119	2921-10/2922-08	154.2
84	2911-09/2912-10	136.2	120	2921-15/2922-03	139.5
85	2911-04/2912-06	130.9	121	2921-03/2922-02	95.8
86	2913-05/2914-02	139.2	122	2921-04/2922-05	149.1
87	2913-07/2914-07	128.2	123	2923-14/2924-02	141.2
88	2913-13/2914-18	134.4	124	2923-05/2924-10	144.7
89	2913-11/2914-17	149.0	125	2923-01/2924-01	155.5
90	2913-19/2914-08	131.4	126	2923-11/2924-11	148.4
91	2913-03/2914-01	142.2	127	2923-15/2924-07	158.5
92	2913-01/2914-05	138.0	128	2923-07/2924-15	144.6
93	2915-11/2916-11	114.6	129	2923-04/2924-09	147.0
94	2915-07/2916-08	135.8	130	2923-03/2924-03	126.6
95	2915-14/2916-14	148.2	131	2925-03/2924-17	123.6
96	2915-04/2916-05	161.4	132	2923-10/2924-04	134.8
97	2915-02/2916-02	162.9	133	2925-04/2926-07	139.7
98	2915-01/2916-15	115.3	134	2925-01/2926-01	122.4
99	2915-13/2916-16	128.7	135	2925-09/2926-05	150.7
100	2915-12/2916-09	162.0	136	2925-06/2926-03	135.5
101	2917-09/2918-02	165.4	137	2925-14/2926-12	146.8
102	2917-08/2918-14	126.1	138	2925-12/2926-11	142.8

Table A4. (Cont.)

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
139	2925-13/2926-04	135.3	175	2937-02/2938-12	137.6
140	2925-08/2926-08	170.6	176	2937-08/2938-04	138.0
141	2925-02/2926-06	151.6	177	2937-03/2938-06	146.4
142	2925-15/2926-14	157.5	178	2937-14/2938-01	164.4
143	2927-17/2928-09	131.4	179	2937-01/2938-02	125.9
144	2927-02/2928-02	131.7	180	2939-12/2940-12	144.6
145	2927-05/2928-13	148.1	181	2939-02/2940-04	116.0
146	2927-01/2928-03	129.5	182	2939-01/2940-03	126.0
147	2927-03/2928-05	120.7	183	2939-08/2940-11	139.1
148	2927-07/2928-07	148.0	184	2939-16/2940-14	144.1
149	2927-06/2928-04	157.8	185	2939-11/2940-15	165.5
150	2929-08/2930-10	150.0	186	2939-14/2940-10	172.2
151	2929-03/2930-12	150.5	187	2941-13/2942-04	140.5
152	2929-10/2930-01	148.1	188	2941-15/2942-15	131.5
153	2929-12/2930-03	156.7	189	2941-05/2942-05	111.3
154	2929-14/2930-07	165.2	190	2943-15/2944-16	158.9
155	2931-08/2932-02	146.9	191	2943-14/2944-14	128.1
156	2931-15/2932-14	161.4	192	2943-05/2944-10	142.1
157	2931-01/2932-17	124.1	193	2945-01/2946-01	139.2
158	2931-12/2932-01	149.5	194	2945-17/2946-10	153.6
159	2933-12/2934-17	146.8	195	2945-03/2946-03	131.9
160	2933-04/2934-05	137.5	196	2945-05/2946-02	148.0
161	2933-07/2934-15	126.7	197	2945-06/2946-07	149.8
162	2933-13/2934-14	155.6	198	2947-03/2948-05	150.5
163	2933-14/2934-16	139.0	199	2947-15/2948-13	138.3
164	2934-10/2935-17	161.1	200	2947-02/2948-02	129.4
165	2933-02/2934-01	154.9	201	2947-06/2948-04	138.8
166	2933-15/2934-02	143.1	202	2947-14/2948-15	134.4
167	2935-03/2936-06	136.2	203	2947-10/2948-16	147.3
168	2935-15/2936-08	145.8	204	2949-09/2950-16	147.8
169	2935-05/2936-10	159.6	205	2949-13/2950-15	148.3
170	2935-01/2936-05	142.1	206	2949-04/2950-04	137.2
171	2935-04/2936-14	139.8	207	2949-01/2950-02	117.6
172	2935-16/2936-13	117.1	208	2949-05/2950-05	137.3
173	2937-13 /2938-03	127.5	209	2949-08/2950-17	134.8
174	2937-04/2938-07	149.4	210	B45/CI31A	94.9

Table A4. (Cont.)

Entry No.	Pedigree†	Yield	Entry No.	Pedigree†	Yield
		(g plant^{-1})			(g plant^{-1})
211	B37/Oh43	117.4	219	BS10(FR)C14	131.2
212	B14/B45	113.6	220	BS11(FR)C14	136.9
213	AES704	90.8	221	DK595	164.4
214	IA5115	94.6	222	DK611	159.3
215	IA5116	89.6	223	DK5738	167.2
216	BS10C0	95.2	224	RX730	160.9
217	BS11C0	75.0	225	P33G26	207.7
218	BS10/BS11)C0	104.5			
	Exp Mean‡	140.2			
	Min Mean§	75.0			
	Max Mean¶	207.7			
	$LSD_{0.05}$#	28.5			
	EEMS††	203.6			

‡ Experimental mean.
§ Minimum mean.
¶ Maximum mean.
# Least significant difference at 0.05 probability level.
†† Effective error mean squares used to calculate pooled error term.

APPENDIX B

MEANS OF GENOTYPES AVERAGED OVER ENVIRONMENTS FOR EACH TRAIT

Table B1. Mean performance of all genotypes averaged across environments.

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
1	2891-07/2892-07	108.8	205	105	17
2	2891-06/2892-12	95.9	208	99	13
3	2891-02/2892-11	114.6	205	104	15
4	2891-08/2892-08	113.6	222	117	15
5	2891-10/2892-05	126.5	213	112	11
6	2891-05/2892-02	102.7	212	106	13
7	2891-01/2892-01	107.2	203	99	15
8	2891-04/2892-03	127.0	221	109	14
9	2891-15/2892-10	110.2	214	110	13
10	2891-03/2892-14	102.4	224	114	15
11	2891-14/2892-13	105.8	240	120	13
12	2893-11/2894-13	110.8	191	88	16
13	2893-07/2894-08	108.0	209	111	15
14	2893-04/2894-18	109.5	219	109	22
15	2893-03/2894-03	117.4	229	117	14
16	2893-06/2894-05	105.2	210	109	12
17	2893-02/2894-16	123.0	222	116	12
18	2893-10/2894-12	112.7	209	109	13
19	2895-15/2896-09	90.6	213	115	15
20	2895-13/2896-03	91.8	212	102	11
21	2895-10/2896-14	103.5	220	111	14
22	2895-01/2896-01	116.1	220	111	14
23	2895-03/2896-06	110.2	241	123	13
24	2895-14/2896-15	109.2	217	106	12
25	2895-04/2896-04	123.8	206	103	11
26	2895-11/2896-08	108.6	199	95	14
27	2895-08/2896-02	102.5	201	93	16
28	2897-06/2898-11	99.0	205	105	14
29	2897-11/2898-04	117.3	225	113	12
30	2897-13/2898-13	106.4	217	112	16
31	2897-10/2898-08	109.2	212	106	15
32	2897-01/2898-02	110.2	215	115	16

† Pedigrees abbreviated. The BS11 plant is listed first and the BS10 after /.
‡ Height measured from soil surface to flag leaf node.
§ Height measured from soil surface to upper ear shank node.
¶ Number of primary tassel branches attached to main spike.

Table B1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
33	2897-08/2898-07	107.6	199	100	15
34	2897-09/2898-12	96.9	217	119	18
35	2899-02/2900-01	102.7	193	93	13
36	2899-14/2900-11	100.7	218	106	14
37	2899-04/2900-05	108.2	204	102	13
38	2899-11/2900-12	107.0	215	113	12
39	2899-06/2900-06	107.0	206	108	17
40	2899-13/2900-08	107.0	209	105	10
41	2899-01/2900-02	110.5	226	127	14
42	2899-07/2900-10	113.9	226	124	15
43	2901-12/2902-06	107.0	229	118	17
44	2901-16/2902-12	119.6	200	108	15
45	2901-15/2902-04	108.7	208	107	16
46	2901-02/2902-07	110.8	225	117	14
47	2901-08/2902-11	104.7	201	103	17
48	2901-01/2902-02	107.8	212	108	14
49	2901-09/2902-10	106.3	219	112	17
50	2901-10/2902-01	117.7	217	108	11
51	2903-16/2904-05	88.5	242	138	20
52	2903-02/2904-14	94.9	201	92	14
53	2903-01/2904-01	110.5	207	104	13
54	2903-14/2904-08	108.4	215	110	12
55	2903-15/2904-16	109.0	219	122	15
56	2905-01/2906-02	104.0	224	116	14
57	2905-12/2906-12	105.7	215	110	16
58	2905-04/2908-03	109.4	211	107	15
59	2905-15/2906-16	114.0	210	110	13
60	2905-10/2906-07	109.3	210	110	13
61	2905-02/2906-05	117.3	218	110	16
62	2905-08/2906-09	108.7	200	102	15
63	2905-17/2906-15	101.7	201	93	12
64	2905-05/2906-03	103.1	218	112	15
65	2905-16/2906-01	95.7	225	117	13
66	2907-01/2908-01	105.7	200	96	15
67	2907-04/2908-07	107.7	205	96	12
68	2907-09/2908-10	101.2	209	107	14

Table B1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
69	2907-06/2908-06	116.6	222	106	13
70	2907-10/2908-14	116.9	220	124	17
71	2907-14/2908-16	106.4	211	115	15
72	2907-02/2908-02	94.7	212	110	16
73	2909-12/2910-16	117.0	232	124	17
74	2909-13/2910-02	102.1	223	108	14
75	2909-04/2910-05	119.0	231	121	15
76	2909-01/2910-03	100.8	204	117	15
77	2909-11/2910-10	98.8	214	110	21
78	2909-02/2910-04	99.5	227	116	15
79	2911-08/2912-14	115.9	221	115	16
80	2911-13/2912-15	108.9	222	107	15
81	2911-03/2912-05	116.0	220	105	10
82	2911-12/2912-12	110.9	213	113	17
83	2911-14/2912-16	108.5	228	118	13
84	2911-09/2912-10	113.8	214	104	15
85	2911-04/2912-06	109.5	197	100	14
86	2913-05/2914-02	113.6	233	121	15
87	2913-07/2914-07	103.8	224	126	21
88	2913-13/2914-18	110.5	206	108	13
89	2913-11/2914-17	106.8	199	105	13
90	2913-19/2914-08	105.9	216	112	16
91	2913-03/2914-01	103.3	211	109	16
92	2913-01/2914-05	113.4	224	108	12
93	2915-11/2916-11	93.5	218	118	14
94	2915-07/2916-08	115.1	234	125	15
95	2915-14/2916-14	102.8	209	100	13
96	2915-04/2916-05	119.1	224	116	12
97	2915-02/2916-02	112.0	220	117	14
98	2915-01/2916-15	99.2	207	96	12
99	2915-13/2916-16	99.8	202	99	13
100	2915-12/2916-09	120.0	224	112	15
101	2917-09/2918-02	128.8	214	110	14
102	2917-08/2918-14	99.7	217	114	16
103	2917-11/2918-11	94.0	223	117	15
104	2917-03/2918-01	110.2	212	109	11

Table B1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
105	2917-13/2918-16	115.4	215	118	13
106	2917-02/2918-03	119.1	221	117	18
107	2917-18/2918-15	103.1	236	128	13
108	2919-11/2920-14	94.6	215	118	18
109	2919-17/2920-16	91.8	191	95	13
110	2919-15/2920-15	108.1	220	116	11
111	2919-04/2920-12	102.2	218	113	12
112	2921-02/2922-01	118.3	213	109	11
113	2921-01/2922-04	107.0	210	107	11
114	2921-13/2922-16	107.9	211	112	14
115	2921-11/2922-14	110.0	208	112	15
116	2921-09/2922-12	123.3	210	102	9
117	2921-14/2922-17	115.7	215	115	15
118	2921-07/2922-13	100.5	213	114	13
119	2921-10/2922-08	103.2	219	110	14
120	2921-15/2922-03	107.9	191	93	13
121	2921-03/2922-02	94.9	210	110	14
122	2921-04/2922-05	101.5	231	122	13
123	2923-14/2924-02	102.9	227	119	13
124	2923-05/2924-10	99.5	211	106	14
125	2923-01/2924-01	117.5	215	112	10
126	2923-11/2924-11	105.3	206	111	13
127	2923-15/2924-07	111.7	225	125	17
128	2923-07/2924-15	98.5	220	125	18
129	2923-04/2924-09	104.7	203	98	13
130	2923-03/2924-03	101.9	207	101	13
131	2925-03/2924-17	104.8	228	128	20
132	2923-10/2924-04	107.6	236	118	11
133	2925-04/2926-07	108.1	222	113	14
134	2925-01/2926-01	102.3	203	112	15
135	2925-09/2926-05	108.6	216	115	14
136	2925-06/2926-03	108.2	205	105	17
137	2925-14/2926-12	100.9	208	101	9
138	2925-12/2926-11	111.1	222	114	12
139	2925-13/2926-04	110.1	226	117	13
140	2925-08/2926-08	113.6	212	117	16

Table B1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
141	2925-02/2926-06	116.8	219	113	18
142	2925-15/2926-14	121.8	225	116	11
143	2927-17/2928-09	107.2	196	100	13
144	2927-02/2928-02	107.3	212	113	12
145	2927-05/2928-13	121.1	217	112	16
146	2927-01/2928-03	104.7	198	96	16
147	2927-03/2928-05	103.5	204	98	18
148	2927-07/2928-07	115.9	213	118	14
149	2927-06/2928-04	114.1	217	115	14
150	2929-08/2930-10	113.4	209	102	10
151	2929-03/2930-12	112.9	200	95	14
152	2929-10/2930-01	116.2	222	109	13
153	2929-12/2930-03	100.8	225	121	15
154	2929-14/2930-07	111.8	229	110	15
155	2931-08/2932-02	118.4	224	117	12
156	2931-15/2932-14	124.1	216	113	13
157	2931-01/2932-17	102.3	216	115	16
158	2931-12/2932-01	115.9	218	104	12
159	2933-12/2934-17	122.7	212	108	12
160	2933-04/2934-05	116.1	226	118	16
161	2933-07/2934-15	100.5	211	109	12
162	2933-13/2934-14	114.9	208	106	16
163	2933-14/2934-16	110.8	222	114	13
164	2934-10/2935-17	107.1	220	111	21
165	2933-02/2934-01	121.4	227	113	12
166	2933-15/2934-02	109.5	218	112	14
167	2935-03/2936-06	107.5	218	111	8
168	2935-15/2936-08	96.1	218	115	13
169	2935-05/2936-10	122.6	234	118	13
170	2935-01/2936-05	112.5	215	115	12
171	2935-04/2936-14	108.0	215	113	15
172	2935-16/2936-13	104.1	219	110	17
173	2937-13 /2938-03	103.7	209	100	12
174	2937-04/2938-07	127.6	226	120	13
175	2937-02/2938-12	91.5	226	121	15
176	2937-08/2938-04	112.9	216	115	14

Table B1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g plant^{-1})	(cm)	(cm)	
177	2937-03/2938-06	118.9	227	120	17
178	2937-14/2938-01	116.7	214	113	18
179	2937-01/2938-02	91.6	203	104	14
180	2939-12/2940-12	107.2	220	119	16
181	2939-02/2940-04	87.7	212	117	15
182	2939-01/2940-03	103.0	227	122	15
183	2939-08/2940-11	114.2	219	112	12
184	2939-16/2940-14	108.9	206	107	13
185	2939-11/2940-15	117.6	229	109	14
186	2939-14/2940-10	130.4	224	116	15
187	2941-13/2942-04	105.0	228	115	16
188	2941-15/2942-15	104.6	222	103	15
189	2941-05/2942-05	84.1	211	109	15
190	2943-15/2944-16	113.7	214	111	16
191	2943-14/2944-14	105.8	215	107	13
192	2943-05/2944-10	109.4	216	109	16
193	2945-01/2946-01	114.3	208	101	13
194	2945-17/2946-10	108.6	223	114	11
195	2945-03/2946-03	111.2	208	108	11
196	2945-05/2946-02	110.4	217	110	13
197	2945-06/2946-07	114.5	230	114	15
198	2947-03/2948-05	114.2	219	111	13
199	2947-15/2948-13	103.5	222	115	13
200	2947-02/2948-02	100.0	186	88	12
201	2947-06/2948-04	107.3	218	117	16
202	2947-14/2948-15	105.5	218	112	21
203	2947-10/2948-16	116.3	216	104	14
204	2949-09/2950-16	103.4	216	113	15
205	2949-13/2950-15	115.0	217	116	10
206	2949-04/2950-04	114.2	212	110	10
207	2949-01/2950-02	103.8	202	99	13
208	2949-05/2950-05	100.9	194	99	9
209	2949-08/2950-17	111.2	216	112	12
210	B45/CI31A	74.2	218	115	12
211	B37/Oh43	82.8	194	77	9
212	B14/B45	77.0	210	100	8

Table B1. (Cont.)

Entry No.	Pedigree†	Yield	Plant Height‡	Ear Height§	Tassel Branch No.¶
		(g $plant^{-1}$)	(cm)	(cm)	
213	AES704	56.6	202	94	10
214	IA5115	70.8	217	110	12
215	IA5116	64.5	206	103	11
216	BS10C0	63.4	200	103	16
217	BS11C0	58.7	215	121	20
218	BS10/BS11)C0	77.5	210	110	17
219	BS10(FR)C14	97.5	218	106	12
220	BS11(FR)C14	95.1	218	105	12
221	DK595	143.9	210	89	6
222	DK611	132.9	206	103	8
223	DK5738	135.9	199	96	8
224	RX730	137.2	205	92	7
225	P33G26	158.1	216	103	6
	EXP MEAN#	107.6	215	110	14
	MIN MEAN††	56.6	186	77	6
	MAX MEAN‡‡	158.1	242	138	22
	$LSD_{0.05}$§§	3.4	4	3	2
	EEMS¶¶	193.43	37.67	28.08	2.04

Experimental mean.
†† Minimum mean.
‡‡ Maximum mean.
§§ Least significant difference at 0.05 probability level.
¶¶ Effective error mean squares.

APPENDIX C

PARENTAL GENOTYPE VALUES

Table C1. Performance of BS10 parental genotypes grown in Ames, IA 2000.

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
1	BS10(FR)C14)2892-07	191.8	231	140	21
2	BS10(FR)C14)2892-12	178.5	219	116	13
3	BS10(FR)C14)2892-11	186.9	215	118	16
4	BS10(FR)C14)2892-08	200.8	273	157	7
5	BS10(FR)C14)2892-05	222.4	250	150	11
6	BS10(FR)C14)2892-02	172.8	237	142	14
7	BS10(FR)C14)2892-01	113.6	216	111	15
8	BS10(FR)C14)2892-03	151.3	233	127	14
9	BS10(FR)C14)2892-10	267.5	262	162	10
10	BS10(FR)C14)2892-14	249.4	240	121	15
11	BS10(FR)C14)2892-13	158.6	228	126	15
12	BS10(FR)C14)2894-13	240.3	205	102	14
13	BS10(FR)C14)2894-08	154.9	250	125	32
14	BS10(FR)C14)2894-18	234.7	222	130	22
15	BS10(FR)C14)2894-03	199.5	261	131	14
16	BS10(FR)C14)2894-05	113.8	187	106	17
17	BS10(FR)C14)2894-16	163.5	245	133	16
18	BS10(FR)C14)2894-12	261.2	221	112	20
19	BS10(FR)C14)2896-09	146.4	235	123	15
20	BS10(FR)C14)2896-03	193.8	245	130	19
21	BS10(FR)C14)2896-14	200.5	248	129	16
22	BS10(FR)C14)2896-01	201.6	227	111	10
23	BS10(FR)C14)2896-06	179.1	274	136	19
24	BS10(FR)C14)2896-15	236.7	247	121	11
25	BS10(FR)C14)2896-04	145.9	204	116	15
26	BS10(FR)C14)2896-08	159.6	210	106	17
27	BS10(FR)C14)2896-02	220.0	213	118	20
28	BS10(FR)C14)2898-11	187.6	234	115	17
29	BS10(FR)C14)2898-04	218.1	234	140	10
30	BS10(FR)C14)2898-13	238.7	227	130	12
31	BS10(FR)C14)2898-08	192.9	205	121	25
32	BS10(FR)C14)2898-02	208.4	215	131	15

† Height measured from soil surface to flag leaf node.
‡ Height measured from soil surface to ear shank node.
§ Number of branches from primary spike.

Table C1. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
33	BS10(FR)C14)2898-07	135.3	218	109	16
34	BS10(FR)C14)2898-12	228.4	252	136	17
35	BS10(FR)C14)2900-01	201.7	189	105	20
36	BS10(FR)C14)2900-11	155.6	225	106	22
37	BS10(FR)C14)2900-05	137.0	209	125	17
38	BS10(FR)C14)2900-12	189.6	248	151	14
39	BS10(FR)C14)2900-06	202.3	241	138	15
40	BS10(FR)C14)2900-08	164.0	229	124	11
41	BS10(FR)C14)2900-02	228.8	237	153	15
42	BS10(FR)C14)2900-10	258.9	257	137	12
43	BS10(FR)C14)2902-06	116.0	241	155	17
44	BS10(FR)C14)2902-12	153.5	225	137	16
45	BS10(FR)C14)2902-04	181.0	228	118	26
46	BS10(FR)C14)2902-07	235.8	242	140	17
47	BS10(FR)C14)2902-11	180.6	227	116	19
48	BS10(FR)C14)2902-02	237.4	248	133	10
49	BS10(FR)C14)2902-10	207.4	268	135	17
50	BS10(FR)C14)2902-01	216.7	236	121	12
51	BS10(FR)C14)2904-05	172.6	273	144	22
52	BS10(FR)C14)2904-14	178.7	223	107	20
53	BS10(FR)C14)2904-01	277.0	217	98	21
54	BS10(FR)C14)2904-08	158.9	222	124	17
55	BS10(FR)C14)2904-16	278.4	236	126	18
56	BS10(FR)C14)2906-02	252.4	243	140	15
57	BS10(FR)C14)2906-12	152.5	253	146	16
58	BS10(FR)C14)2908-03	214.8	241	151	13
59	BS10(FR)C14)2906-16	271.4	210	120	20
60	BS10(FR)C14)2906-07	187.7	229	123	13
61	BS10(FR)C14)2906-05	144.6	215	114	21
62	BS10(FR)C14)2906-09	212.4	220	126	19
63	BS10(FR)C14)2906-15	183.5	194	97	12
64	BS10(FR)C14)2906-03	222.1	251	138	10
65	BS10(FR)C14)2906-01	219.2	242	139	11
66	BS10(FR)C14)2908-01	200.9	215	104	19
67	BS10(FR)C14)2908-07	231.8	232	127	16
68	BS10(FR)C14)2908-10	174.4	241	122	14

Table C1. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
69	BS10(FR)C14)2908-06	192.8	265	145	14
70	BS10(FR)C14)2908-14	163.5	255	161	14
71	BS10(FR)C14)2908-16	168.3	210	118	18
72	BS10(FR)C14)2908-02	187.6	224	133	24
73	BS10(FR)C14)2910-16	166.0	264	136	19
74	BS10(FR)C14)2910-02	197.1	238	120	18
75	BS10(FR)C14)2910-05	142.0	246	141	17
76	BS10(FR)C14)2910-03	206.4	221	131	14
77	BS10(FR)C14)2910-10	184.3	238	116	28
78	BS10(FR)C14)2910-04	197.4	261	139	16
79	BS10(FR)C14)2912-14	191.9	256	115	18
80	BS10(FR)C14)2912-15	198.1	245	125	16
81	BS10(FR)C14)2912-05	195.7	261	129	17
82	BS10(FR)C14)2912-12	194.4	215	151	24
83	BS10(FR)C14)2912-16	174.5	232	108	13
84	BS10(FR)C14)2912-10	184.2	253	137	14
85	BS10(FR)C14)2912-06	166.0	225	104	19
86	BS10(FR)C14)2914-02	199.2	248	139	9
87	BS10(FR)C14)2914-07	167.9	254	156	22
88	BS10(FR)C14)2914-18	191.0	190	92	12
89	BS10(FR)C14)2914-17	169.6	207	131	19
90	BS10(FR)C14)2914-08	161.9	218	123	21
91	BS10(FR)C14)2914-01	236.6	249	113	21
92	BS10(FR)C14)2914-05	210.7	260	132	12
93	BS10(FR)C14)2916-11	179.8	259	160	15
94	BS10(FR)C14)2916-08	193.9	264	142	16
95	BS10(FR)C14)2916-14	177.6	227	116	13
96	BS10(FR)C14)2916-05	178.0	239	141	16
97	BS10(FR)C14)2916-02	166.3	235	140	25
98	BS10(FR)C14)2916-15	177.1	230	116	15
99	BS10(FR)C14)2916-16	169.4	178	110	12
100	BS10(FR)C14)2916-09	102.0	229	118	10
101	BS10(FR)C14)2918-02	220.0	258	145	19
102	BS10(FR)C14)2918-14	157.8	231	132	26
103	BS10(FR)C14)2918-11	143.3	254	138	20
104	BS10(FR)C14)2918-01	247.4	224	109	8

Table C1. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
105	BS10(FR)C14)2918-16	214.3	243	133	11
106	BS10(FR)C14)2918-03	191.6	244	118	18
107	BS10(FR)C14)2918-15	169.5	276	151	18
108	BS10(FR)C14)2920-14	160.7	244	132	15
109	BS10(FR)C14)2920-16	170.6	175	102	17
110	BS10(FR)C14)2920-15	239.5	230	137	13
111	BS10(FR)C14)2920-12	190.2	267	144	11
112	BS10(FR)C14)2922-01	237.5	221	113	18
113	BS10(FR)C14)2922-04	153.9	232	120	16
114	BS10(FR)C14)2922-16	207.4	241	143	12
115	BS10(FR)C14)2922-14	174.8	235	133	22
116	BS10(FR)C14)2922-12	148.5	234	132	17
117	BS10(FR)C14)2922-17	161.1	201	115	15
118	BS10(FR)C14)2922-13	164.6	224	134	23
119	BS10(FR)C14)2922-08	131.7	251	125	19
120	BS10(FR)C14)2922-03	137.9	206	102	13
121	BS10(FR)C14)2922-02	167.9	229	132	17
122	BS10(FR)C14)2922-05	204.9	252	139	14
123	BS10(FR)C14)2924-02	242.4	260	135	18
124	BS10(FR)C14)2924-10	150.6	229	132	23
125	BS10(FR)C14)2924-01	201.1	234	127	12
126	BS10(FR)C14)2924-11	176.6	212	123	18
127	BS10(FR)C14)2924-07	184.2	273	160	11
128	BS10(FR)C14)2924-15	198.9	262	143	11
129	BS10(FR)C14)2924-09	233.5	239	152	21
130	BS10(FR)C14)2924-03	202.9	244	123	12
131	BS10(FR)C14)2924-17	185.6	230	144	16
132	BS10(FR)C14)2924-04	177.3	235	134	11
133	BS10(FR)C14)2926-07	233.4	277	156	12
134	BS10(FR)C14)2926-01	210.6	220	125	16
135	BS10(FR)C14)2926-05	216.8	236	123	16
136	BS10(FR)C14)2926-03	194.8	236	138	27
137	BS10(FR)C14)2926-12	241.8	228	126	18
138	BS10(FR)C14)2926-11	204.3	243	117	11
139	BS10(FR)C14)2926-04	194.3	246	131	21
140	BS10(FR)C14)2926-08	212.4	247	159	13

Table C1. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
141	BS10(FR)C14)2926-06	206.1	252	145	19
142	BS10(FR)C14)2926-14	200.2	231	144	10
143	BS10(FR)C14)2928-09	184.8	236	126	19
144	BS10(FR)C14)2928-02	230.6	232	131	13
145	BS10(FR)C14)2928-13	258.9	224	119	18
146	BS10(FR)C14)2928-03	174.2	217	109	20
147	BS10(FR)C14)2928-05	167.2	198	97	19
148	BS10(FR)C14)2928-07	183.4	238	154	18
149	BS10(FR)C14)2928-04	196.0	250	146	18
150	BS10(FR)C14)2930-10	134.7	215	132	22
151	BS10(FR)C14)2930-12	99.5	212	102	22
152	BS10(FR)C14)2930-01	266.7	249	150	11
153	BS10(FR)C14)2930-03	181.4	244	137	16
154	BS10(FR)C14)2930-07	161.5	242	135	19
155	BS10(FR)C14)2932-02	210.1	258	135	14
156	BS10(FR)C14)2932-14	206.5	213	120	23
157	BS10(FR)C14)2932-17	224.7	222	118	25
158	BS10(FR)C14)2932-01	207.1	237	122	18
159	BS10(FR)C14)2934-17	273.3	227	120	14
160	BS10(FR)C14)2934-05	158.2	247	146	17
161	BS10(FR)C14)2934-15	173.1	261	159	17
162	BS10(FR)C14)2934-14	149.6	222	120	21
163	BS10(FR)C14)2934-16	201.4	253	131	21
164	BS10(FR)C14)2934-10	147.1	243	112	24
165	BS10(FR)C14)2934-01	273.2	225	128	15
166	BS10(FR)C14)2934-02	172.2	211	109	18
167	BS10(FR)C14)2936-06	120.0	245	142	10
168	BS10(FR)C14)2936-08	220.4	252	145	15
169	BS10(FR)C14)2936-10	162.2	259	128	17
170	BS10(FR)C14)2936-05	194.1	239	145	15
171	BS10(FR)C14)2936-14	207.7	217	117	16
172	BS10(FR)C14)2936-13	216.8	232	129	22
173	BS10(FR)C14)2938-03	160.1	212	122	19
174	BS10(FR)C14)2938-07	209.9	242	142	21
175	BS10(FR)C14)2938-12	156.2	247	150	21
176	BS10(FR)C14)2937-04	195.5	245	123	20

Table C1. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g $plant^{-1}$)	(cm)	(cm)	
177	BS10(FR)C14)2938-06	135.7	275	161	16
178	BS10(FR)C14)2938-01	189.2	260	121	21
179	BS10(FR)C14)2938-02	145.6	222	110	23
180	BS10(FR)C14)2940-12	178.2	253	145	14
181	BS10(FR)C14)2940-04	196.4	242	142	22
182	BS10(FR)C14)2940-03	247.4	250	144	18
183	BS10(FR)C14)2940-11	204.3	247	138	12
184	BS10(FR)C14)2940-14	193.1	228	132	19
185	BS10(FR)C14)2940-15	202.5	224	113	19
186	BS10(FR)C14)2940-10	184.7	266	140	16
187	BS10(FR)C14)2942-04	208.3	248	147	22
188	BS10(FR)C14)2942-15	162.9	216	108	22
189	BS10(FR)C14)2942-05	193.8	257	135	15
190	BS10(FR)C14)2944-16	244.0	243	139	18
191	BS10(FR)C14)2944-14	261.0	253	135	18
192	BS10(FR)C14)2944-10	209.0	260	139	18
193	BS10(FR)C14)2946-01	273.4	218	127	20
194	BS10(FR)C14)2946-10	166.2	246	140	7
195	BS10(FR)C14)2946-03	191.6	237	144	12
196	BS10(FR)C14)2946-02	145.8	239	128	14
197	BS10(FR)C14)2946-07	136.5	254	152	24
198	BS10(FR)C14)2948-05	212.7	255	140	16
199	BS10(FR)C14)2948-13	84.8	233	121	16
200	BS10(FR)C14)2948-02	141.8	165	82	14
201	BS10(FR)C14)2948-04	171.9	221	120	18
202	BS10(FR)C14)2948-15	187.7	234	116	21
203	BS10(FR)C14)2948-16	241.2	236	119	19
204	BS10(FR)C14)2950-16	202.7	237	121	18
205	BS10(FR)C14)2950-15	227.9	223	117	18
206	BS10(FR)C14)2950-04	215.0	229	124	13
207	BS10(FR)C14)2950-02	193.2	208	107	10
208	BS10(FR)C14)2950-05	210.5	191	103	14
209	BS10(FR)C14)2950-17	296.9	183	102	8
	Mean	192.5	235	129	17
	Standard Deviation	36.5	20	15	4

Table C2. Performance of BS11 parental genotypes grown in Ames, IA 2000.

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
1	BS11(FR)C14)2891-07	167.7	228	115	18
2	BS11(FR)C14)2891-06	167.3	246	132	10
3	BS11(FR)C14)2891-02	204.9	201	119	24
4	BS11(FR)C14)2891-08	218.0	241	136	13
5	BS11(FR)C14)2891-10	156.6	240	132	12
6	BS11(FR)C14)2891-05	130.5	231	124	14
7	BS11(FR)C14)2891-01	167.5	185	94	13
8	BS11(FR)C14)2891-04	161.9	266	130	7
9	BS11(FR)C14)2891-15	194.6	223	113	19
10	BS11(FR)C14)2891-03	274.4	239	139	16
11	BS11(FR)C14)2891-14	204.8	273	131	9
12	BS11(FR)C14)2893-11	151.0	236	106	24
13	BS11(FR)C14)2893-07	216.1	250	146	14
14	BS11(FR)C14)2893-04	189.1	257	134	23
15	BS11(FR)C14)2893-03	176.3	264	154	14
16	BS11(FR)C14)2893-06	177.7	225	144	9
17	BS11(FR)C14)2893-02	200.8	265	141	13
18	BS11(FR)C14)2893-10	173.4	247	135	14
19	BS11(FR)C14)2895-15	232.6	256	126	15
20	BS11(FR)C14)2895-13	166.0	230	101	12
21	BS11(FR)C14)2895-10	180.5	244	122	22
22	BS11(FR)C14)2895-01	223.6	265	133	19
23	BS11(FR)C14)2895-03	224.6	277	140	11
24	BS11(FR)C14)2895-14	211.7	234	106	16
25	BS11(FR)C14)2895-04	181.7	258	117	14
26	BS11(FR)C14)2895-11	180.3	243	96	20
27	BS11(FR)C14)2895-08	168.6	230	112	25
28	BS11(FR)C14)2897-06	126.8	224	134	23
29	BS11(FR)C14)2897-11	175.2	273	155	3
30	BS11(FR)C14)2897-13	263.3	234	130	17
31	BS11(FR)C14)2897-10	173.8	235	118	25
32	BS11(FR)C14)2897-01	232.4	238	130	10

† Height measured from soil surface to flag leaf node.
‡ Height measured from soil surface to ear shank node.
§ Number of branches from primary spike.

Table C2. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
33	BS11(FR)C14)2897-08	165.8	225	118	21
34	BS11(FR)C14)2897-09	205.5	252	130	15
35	BS11(FR)C14)2899-20	187.1	207	98	10
36	BS11(FR)C14)2899-14	198.1	222	117	12
37	BS11(FR)C14)2899-04	149.3	235	122	19
38	BS11(FR)C14)2899-11	242.1	257	134	15
39	BS11(FR)C14)2899-06	171.8	205	137	28
40	BS11(FR)C14)2899-13	243.9	259	140	12
41	BS11(FR)C14)2899-01	215.8	251	132	11
42	BS11(FR)C14)2899-07	183.2	259	143	11
43	BS11(FR)C14)2901-12	196.2	273	144	7
44	BS11(FR)C14)2901-16	212.1	244	99	11
45	BS11(FR)C14)2901-15	171.2	232	116	18
46	BS11(FR)C14)2901-02	204.5	253	127	15
47	BS11(FR)C14)2901-08	174.1	201	133	24
48	BS11(FR)C14)2901-01	226.6	232	128	17
49	BS11(FR)C14)2901-09	228.4	272	145	24
50	BS11(FR)C14)2901-10	172.6	260	132	8
51	BS11(FR)C14)2903-16	221.0	273	147	20
52	BS11(FR)C14)2903-02	242.3	237	110	13
53	BS11(FR)C14)2903-01	225.6	213	97	13
54	BS11(FR)C14)2903-14	206.3	248	118	15
55	BS11(FR)C14)2903-15	169.6	238	143	21
56	BS11(FR)C14)2905-01	214.6	243	113	17
57	BS11(FR)C14)2905-12	170.2	256	144	15
58	BS11(FR)C14)2905-04	153.3	264	144	13
59	BS11(FR)C14)2905-15	212.8	245	134	14
60	BS11(FR)C14)2905-10	141.3	252	137	9
61	BS11(FR)C14)2905-02	190.5	247	117	11
62	BS11(FR)C14)2905-08	211.8	241	151	24
63	BS11(FR)C14)2905-17	182.0	212	100	10
64	BS11(FR)C14)2905-05	137.6	225	120	12
65	BS11(FR)C14)2905-16	226.4	277	152	16
66	BS11(FR)C14)2907-01	232.9	175	75	17
67	BS11(FR)C14)2907-04	168.1	258	140	18
68	BS11(FR)C14)2907-09	114.0	236	100	19

Table C2. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
69	BS11(FR)C14)2907-06	127.5	252	135	6
70	BS11(FR)C14)2907-10	270.0	283	152	18
71	BS11(FR)C14)2907-14	207.5	237	120	24
72	BS11(FR)C14)2907-02	194.5	229	116	19
73	BS11(FR)C14)2909-12	190.4	261	149	23
74	BS11(FR)C14)2909-13	205.3	254	121	17
75	BS11(FR)C14)2909-04	225.1	254	112	15
76	BS11(FR)C14)2909-01	201.1	238	133	20
77	BS11(FR)C14)2909-11	197.6	269	153	20
78	BS11(FR)C14)2909-02	192.7	258	129	24
79	BS11(FR)C14)2911-08	198.3	267	121	16
80	BS11(FR)C14)2911-13	147.1	241	111	10
81	BS11(FR)C14)2911-03	211.7	248	116	14
82	BS11(FR)C14)2911-12	194.6	239	106	22
83	BS11(FR)C14)2911-14	174.2	236	115	23
84	BS11(FR)C14)2911-09	186.1	243	123	16
85	BS11(FR)C14)2911-04	215.9	254	146	17
86	BS11(FR)C14)2913-05	177.7	277	132	18
87	BS11(FR)C14)2913-07	181.7	220	151	44
88	BS11(FR)C14)2913-13	193.3	241	123	21
89	BS11(FR)C14)2913-11	127.0	234	121	14
90	BS11(FR)C14)2913-19	325.9	277	147	21
91	BS11(FR)C14)2913-03	190.5	230	141	20
92	BS11(FR)C14)2913-01	200.2	235	107	24
93	BS11(FR)C14)2915-11	199.4	263	162	13
94	BS11(FR)C14)2915-07	190.5	262	160	19
95	BS11(FR)C14)2915-14	226.0	226	105	11
96	BS11(FR)C14)2915-04	183.9	255	135	17
97	BS11(FR)C14)2915-02	157.0	250	135	10
98	BS11(FR)C14)2915-01	156.9	222	90	13
99	BS11(FR)C14)2915-13	164.3	229	106	15
100	BS11(FR)C14)2915-12	176.7	267	157	17
101	BS11(FR)C14)2917-09	193.2	253	120	18
102	BS11(FR)C14)2917-08	135.3	256	146	20
103	BS11(FR)C14)2917-11	170.8	265	144	19
104	BS11(FR)C14)2917-03	171.9	259	125	13

Table C2. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
105	BS11(FR)C14)2917-13	158.6	269	149	15
106	BS11(FR)C14)2917-02	194.8	230	111	18
107	BS11(FR)C14)2917-18	185.4	277	145	17
108	BS11(FR)C14)2919-11	205.7	264	149	33
109	BS11(FR)C14)2919-17	195.6	188	91	14
110	BS11(FR)C14)2919-15	165.2	241	130	14
111	BS11(FR)C14)2919-04	142.4	267	154	12
112	BS11(FR)C14)2921-02	174.9	219	114	11
113	BS11(FR)C14)2921-01	169.9	231	110	10
114	BS11(FR)C14)2921-13	124.1	230	126	15
115	BS11(FR)C14)2921-11	130.7	208	116	20
116	BS11(FR)C14)2921-09	189.5	268	131	9
117	BS11(FR)C14)2921-14	243.6	256	141	16
118	BS11(FR)C14)2921-07	176.3	259	152	22
119	BS11(FR)C14)2921-10	175.9	261	120	19
120	BS11(FR)C14)2921-15	195.9	205	95	16
121	BS11(FR)C14)2921-03	139.0	225	128	18
122	BS11(FR)C14)2921-04	197.1	256	118	19
123	BS11(FR)C14)2923-14	234.3	276	151	15
124	BS11(FR)C14)2923-05	167.8	258	115	6
125	BS11(FR)C14)2923-01	199.9	221	100	11
126	BS11(FR)C14)2923-11	204.7	255	149	13
127	BS11(FR)C14)2923-15	191.1	212	150	20
128	BS11(FR)C14)2923-07	205.7	258	158	18
129	BS11(FR)C14)2923-04	189.9	254	142	18
130	BS11(FR)C14)2923-03	148.6	193	111	19
131	BS11(FR)C14)2925-03	177.4	276	158	19
132	BS11(FR)C14)2923-10	155.8	263	143	20
133	BS11(FR)C14)2925-04	187.7	263	148	15
134	BS11(FR)C14)2925-01	260.9	198	115	20
135	BS11(FR)C14)2925-09	261.3	243	134	20
136	BS11(FR)C14)2925-06	179.8	217	110	18
137	BS11(FR)C14)2925-14	161.9	222	105	10
138	BS11(FR)C14)2925-12	173.0	249	129	21
139	BS11(FR)C14)2925-13	176.4	256	141	14
140	BS11(FR)C14)2925-08	204.5	275	152	25

Table C2. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
141	BS11(FR)C14)2925-02	167.1	235	123	15
142	BS11(FR)C14)2925-15	128.6	231	114	21
143	BS11(FR)C14)2927-17	132.8	193	107	13
144	BS11(FR)C14)2927-02	233.1	220	124	21
145	BS11(FR)C14)2927-05	181.7	261	137	13
146	BS11(FR)C14)2927-01	141.5	244	107	18
147	BS11(FR)C14)2927-03	188.5	226	120	24
148	BS11(FR)C14)2927-07	206.6	266	165	20
149	BS11(FR)C14)2927-06	176.2	267	124	13
150	BS11(FR)C14)2929-08	192.0	242	118	12
151	BS11(FR)C14)2929-03	173.4	207	83	7
152	BS11(FR)C14)2929-10	163.6	252	125	11
153	BS11(FR)C14)2929-12	170.5	267	134	16
154	BS11(FR)C14)2929-14	157.4	260	105	17
155	BS11(FR)C14)2931-08	191.5	275	145	16
156	BS11(FR)C14)2931-15	206.1	268	142	11
157	BS11(FR)C14)2931-01	246.8	220	116	20
158	BS11(FR)C14)2931-12	164.7	252	120	12
159	BS11(FR)C14)2933-12	91.1	253	138	17
160	BS11(FR)C14)2933-04	170.8	250	131	23
161	BS11(FR)C14)2933-07	181.2	230	114	12
162	BS11(FR)C14)2933-13	146.3	209	112	12
163	BS11(FR)C14)2933-14	159.5	240	116	12
164	BS11(FR)C14)2935-17	163.5	213	104	24
165	BS11(FR)C14)2933-02	248.4	283	149	11
166	BS11(FR)C14)2933-15	229.9	247	113	18
167	BS11(FR)C14)2935-03	238.9	260	126	16
168	BS11(FR)C14)2935-15	138.5	206	102	20
169	BS11(FR)C14)2935-05	187.6	282	165	11
170	BS11(FR)C14)2935-01	254.1	239	131	14
171	BS11(FR)C14)2935-04	161.7	248	137	14
172	BS11(FR)C14)2935-16	210.8	247	106	37
173	BS11(FR)C14)2937-13	148.6	240	111	13
174	BS11(FR)C14)2937-04	203.2	260	152	8
175	BS11(FR)C14)2937-02	219.7	253	125	27
176	BS11(FR)C14)2937-08	207.2	284	165	10

Table C2. (Cont.)

Entry No.	Pedigree	Yield	Plant Height†	Ear Height‡	Tassel Branch No.§
		(g plant^{-1})	(cm)	(cm)	
177	BS11(FR)C14)2937-04	195.5	276	148	15
178	BS11(FR)C14)2937-03	200.6	226	119	11
179	BS11(FR)C14)2937-14	182.7	235	132	22
180	BS11(FR)C14)2937-01	240.9	248	149	17
181	BS11(FR)C14)2939-12	160.6	218	121	23
182	BS11(FR)C14)2939-02	187.2	244	114	21
183	BS11(FR)C14)2939-01	239.0	286	160	17
184	BS11(FR)C14)2939-08	158.1	240	102	19
185	BS11(FR)C14)2939-16	228.3	271	142	13
186	BS11(FR)C14)2939-11	181.6	232	127	13
187	BS11(FR)C14)2939-14	171.0	250	146	29
188	BS11(FR)C14)2941-13	164.8	258	120	11
189	BS11(FR)C14)2941-15	264.6	255	134	18
190	BS11(FR)C14)2941-05	189.7	225	134	11
191	BS11(FR)C14)2943-15	177.9	243	115	13
192	BS11(FR)C14)2943-14	195.6	252	143	18
193	BS11(FR)C14)2943-05	169.8	243	97	18
194	BS11(FR)C14)2945-01	171.0	252	138	11
195	BS11(FR)C14)2945-17	183.0	265	129	13
196	BS11(FR)C14)2945-03	186.2	263	147	12
197	BS11(FR)C14)2945-05	176.1	275	138	29
198	BS11(FR)C14)2945-06	169.8	248	102	20
199	BS11(FR)C14)2947-03	183.0	218	112	22
200	BS11(FR)C14)2947-15	158.5	229	90	9
201	BS11(FR)C14)2947-02	193.7	236	123	21
202	BS11(FR)C14)2947-06	159.8	223	115	16
203	BS11(FR)C14)2947-14	254.8	247	132	16
204	BS11(FR)C14)2947-10	191.7	260	130	21
205	BS11(FR)C14)2949-09	227.5	216	126	15
206	BS11(FR)C14)2949-13	131.5	242	125	7
207	BS11(FR)C14)2949-04	121.1	220	110	22
208	BS11(FR)C14)2949-01	204.4	237	118	11
209	BS11(FR)C14)2949-05	152.2	270	151	13
	Mean	188.1	235	129	17
	Standard Deviation	32.0	20	15	4

Table C3. Midparent values used in regression analysis.

Entry No.	Yield†	Plant Height	Ear Height	Tassel Branch No.
	(g plant^{-1})	(cm)	(cm)	
1	179.8	230	128	20
2	172.9	233	124	12
3	195.9	208	119	20
4	209.4	257	147	10
5	189.5	245	141	12
6	151.7	234	133	14
7	140.6	201	103	14
8	156.6	250	129	11
9	231.1	243	138	15
10	261.9	240	130	16
11	181.7	251	129	12
12	145.7	221	104	19
13	185.5	250	136	7
14	211.9	240	132	23
15	187.9	263	143	14
16	145.8	206	125	13
17	182.2	255	137	15
18	167.3	234	124	17
19	189.5	246	125	15
20	179.9	238	116	16
21	190.5	246	126	19
22	212.6	246	122	15
23	201.9	276	138	15
24	224.2	241	114	14
25	163.8	231	117	15
26	170.0	227	101	19
27	194.3	222	115	23
28	157.2	229	125	20
29	196.7	254	148	7
30	251.0	231	130	15
31	183.4	220	120	25
32	220.4	227	131	13

† All measurements average of entry numbers from BS10 and BS11. Example Midparent entry 1 = (BS10 + BS11)/2.

Table C3. (Cont.)

Entry No.	Yield†	Plant Height	Ear Height	Tassel Branch No.
	(g plant^{-1})	(cm)	(cm)	
33	150.6	222	114	19
34	217.0	252	133	16
35	194.4	198	102	15
36	176.9	224	112	17
37	143.2	222	124	18
38	215.9	253	143	15
39	187.1	223	138	22
40	204.0	244	132	12
41	222.3	244	143	13
42	221.1	258	140	12
43	156.1	257	150	12
44	182.8	235	118	14
45	176.1	230	117	22
46	220.2	248	134	16
47	177.4	214	125	22
48	232.0	240	131	14
49	217.9	270	140	21
50	194.7	248	127	10
51	196.8	273	146	21
52	210.5	230	109	17
53	251.3	215	98	17
54	182.6	235	121	16
55	224.0	237	135	20
56	233.5	243	127	16
57	161.4	255	145	16
58	184.1	253	148	13
59	242.1	228	127	17
60	164.5	241	130	11
61	167.6	231	116	16
62	212.1	231	139	22
63	182.8	203	99	11
64	179.9	238	129	11
65	222.8	260	146	14
66	216.9	195	90	18
67	200.0	245	134	17
68	144.2	239	111	17

Table C3. (Cont.)

Entry No.	Yield†	Plant Height	Ear Height	Tassel Branch No.
	(g plant^{-1})	(cm)	(cm)	
69	160.2	259	140	10
70	216.8	269	157	16
71	187.9	224	119	21
72	191.1	227	125	22
73	178.2	263	143	21
74	201.2	246	121	18
75	183.6	250	127	16
76	203.8	230	132	17
77	191.0	254	135	24
78	195.1	260	134	20
79	195.1	262	118	17
80	172.6	243	118	13
81	203.7	255	123	16
82	194.5	227	129	23
83	174.4	234	112	18
84	185.2	248	130	15
85	191.0	240	125	18
86	188.5	263	136	14
87	174.8	237	154	33
88	192.2	216	108	17
89	148.3	221	126	17
90	243.9	248	135	21
91	213.6	240	127	21
92	205.5	248	120	18
93	189.6	261	161	14
94	192.2	263	151	18
95	201.8	227	111	12
96	181.0	247	138	17
97	161.7	243	138	18
98	167.0	226	103	14
99	166.9	204	108	14
100	139.4	248	138	14
101	206.6	256	133	19
102	146.6	244	139	23
103	157.1	260	141	20
104	209.7	242	117	11

Table C3. (Cont.)

Entry No.	Yield†	Plant Height	Ear Height	Tassel Branch No.
	(g plant^{-1})	(cm)	(cm)	
105	186.5	256	141	13
106	193.2	237	115	18
107	177.5	277	148	18
108	183.2	254	141	24
109	183.1	182	97	16
110	202.4	236	134	14
111	166.3	267	149	12
112	206.2	220	114	15
113	161.9	232	115	13
114	165.8	236	135	14
115	152.8	222	125	21
116	169.0	251	132	13
117	202.4	229	128	16
118	170.5	242	143	23
119	153.8	256	123	19
120	166.9	206	99	15
121	153.5	227	130	18
122	201.0	254	129	17
123	238.4	268	143	17
124	159.2	244	124	15
125	200.5	228	114	12
126	190.7	234	136	16
127	187.7	243	155	16
128	202.3	260	151	15
129	211.7	247	147	20
130	175.8	219	117	16
131	181.5	253	151	18
132	166.6	249	139	16
133	210.6	270	152	14
134	235.8	209	120	18
135	239.1	240	129	18
136	187.3	227	124	23
137	201.9	225	116	14
138	188.7	246	123	12
139	185.4	251	136	18
140	208.5	261	156	19

Table C3. (Cont.)

Entry No.	Yield†	Plant Height	Ear Height	Tassel Branch No.
	(g $plant^{-1}$)	(cm)	(cm)	
141	186.6	244	134	17
142	164.4	231	129	16
143	158.8	215	117	16
144	231.9	226	128	17
145	220.3	243	128	16
146	157.9	231	108	19
147	177.9	212	109	22
148	195.0	252	160	19
149	186.1	259	135	16
150	163.4	229	125	17
151	136.5	210	93	15
152	215.2	251	138	11
153	176.0	256	136	16
154	159.5	251	120	18
155	200.8	267	140	15
156	206.3	241	131	17
157	235.8	221	117	23
158	185.9	245	121	15
159	182.2	240	129	16
160	164.5	249	139	20
161	177.2	246	137	15
162	148.0	216	116	17
163	180.5	247	124	17
164	155.3	228	108	24
165	260.8	254	139	13
166	201.1	229	111	18
167	179.5	253	134	13
168	179.5	229	124	18
169	174.9	271	147	14
170	224.1	239	138	15
171	184.7	233	127	15
172	213.8	240	118	30
173	154.4	226	117	16
174	206.6	251	147	15
175	188.0	250	138	24
176	201.4	265	144	15

Table C3. (Cont.)

Entry No.	Yield†	Plant Height	Ear Height	Tassel Branch No.
	(g plant^{-1})	(cm)	(cm)	
177	168.2	276	155	16
178	186.0	243	120	16
179	193.3	229	121	23
180	169.4	251	147	16
181	191.8	230	132	23
182	243.2	247	129	20
183	181.2	267	149	15
184	210.7	234	117	19
185	192.1	248	128	16
186	177.9	249	134	15
187	186.6	249	147	26
188	213.8	237	114	17
189	191.8	256	135	17
190	211.0	234	137	15
191	228.3	248	125	16
192	189.4	256	141	18
193	222.2	231	112	19
194	174.6	249	139	9
195	188.9	251	137	13
196	161.0	251	138	13
197	153.2	265	145	27
198	197.9	252	121	18
199	121.7	226	117	19
200	167.8	197	86	12
201	165.9	229	122	20
202	221.3	229	116	19
203	216.5	242	126	18
204	215.1	249	126	20
205	179.7	220	122	17
206	168.1	236	125	10
207	198.8	214	109	16
208	181.4	214	111	13
209	228.8	227	127	11
Mean	189.5	240	128	16
Standard Deviation	25.8	17	14	4

APPENDIX D

MIDPARENT-OFFSPRING REGRESSION GRAPHS FOR TRAITS AT INDIVIDAUL ENVIRONMENTS AND AVERAGED ACROSS ALL ENVIRONMENTS

Figure D1. Midparent-offspring regression graphs of yield (g/plant) of maize at four environments in Iowa measured in 2001.

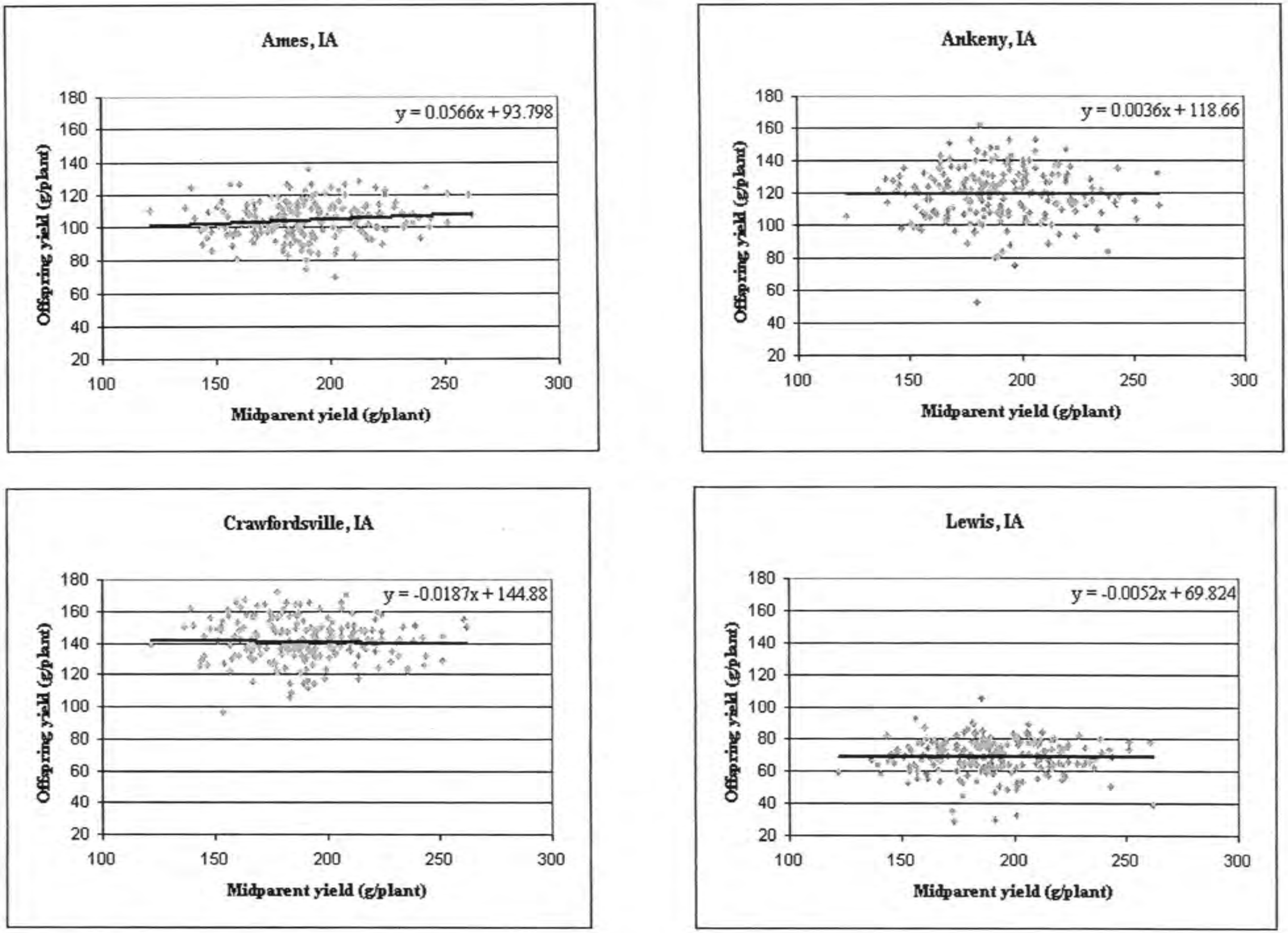
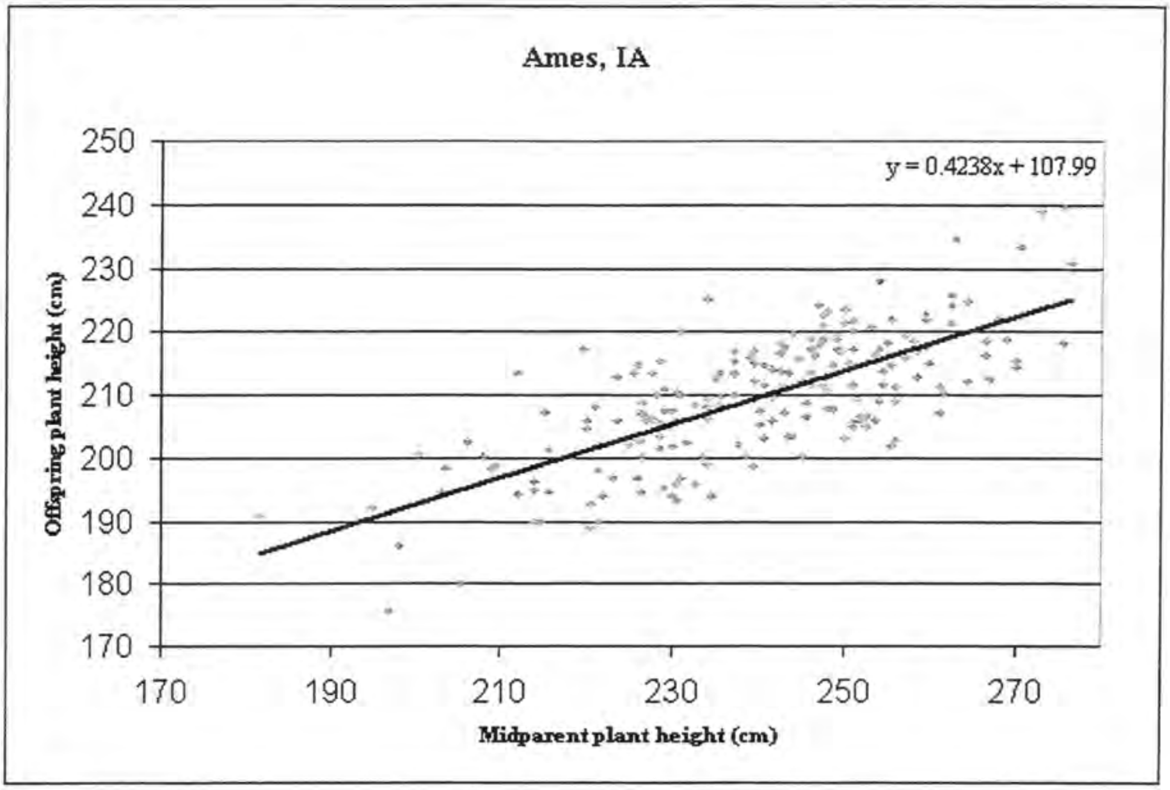


Figure D2. Midparent-offspring regression graphs of plant height (cm) of maize at two environments in Iowa measured in 2001.



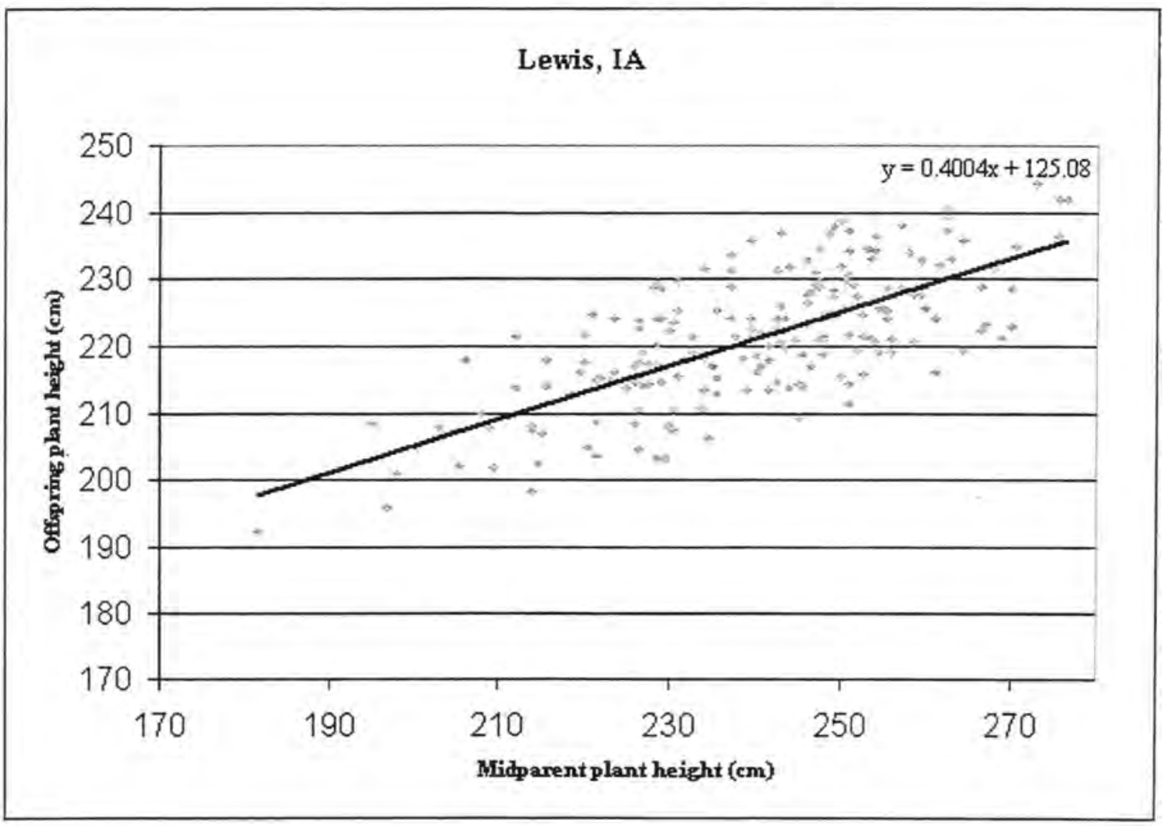
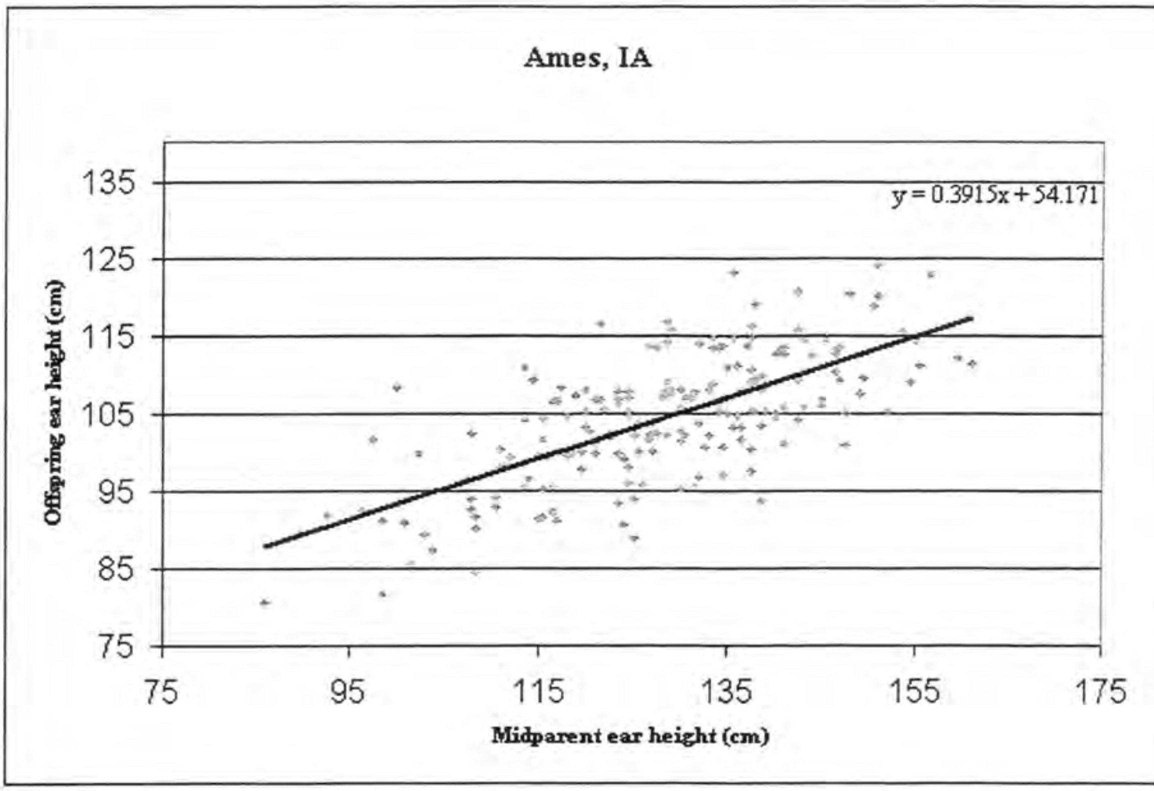


Figure D3. Midparent-offspring regression graphs of ear height (cm) of maize at two environments in Iowa measured in 2001.



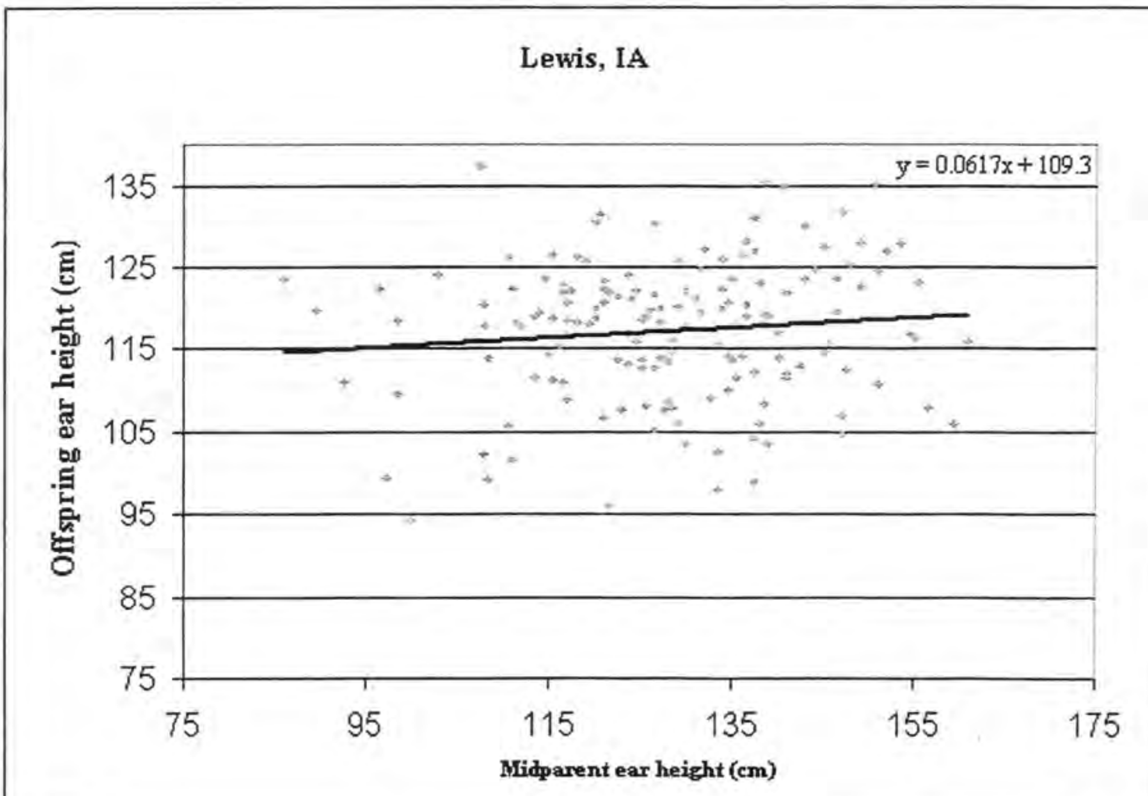
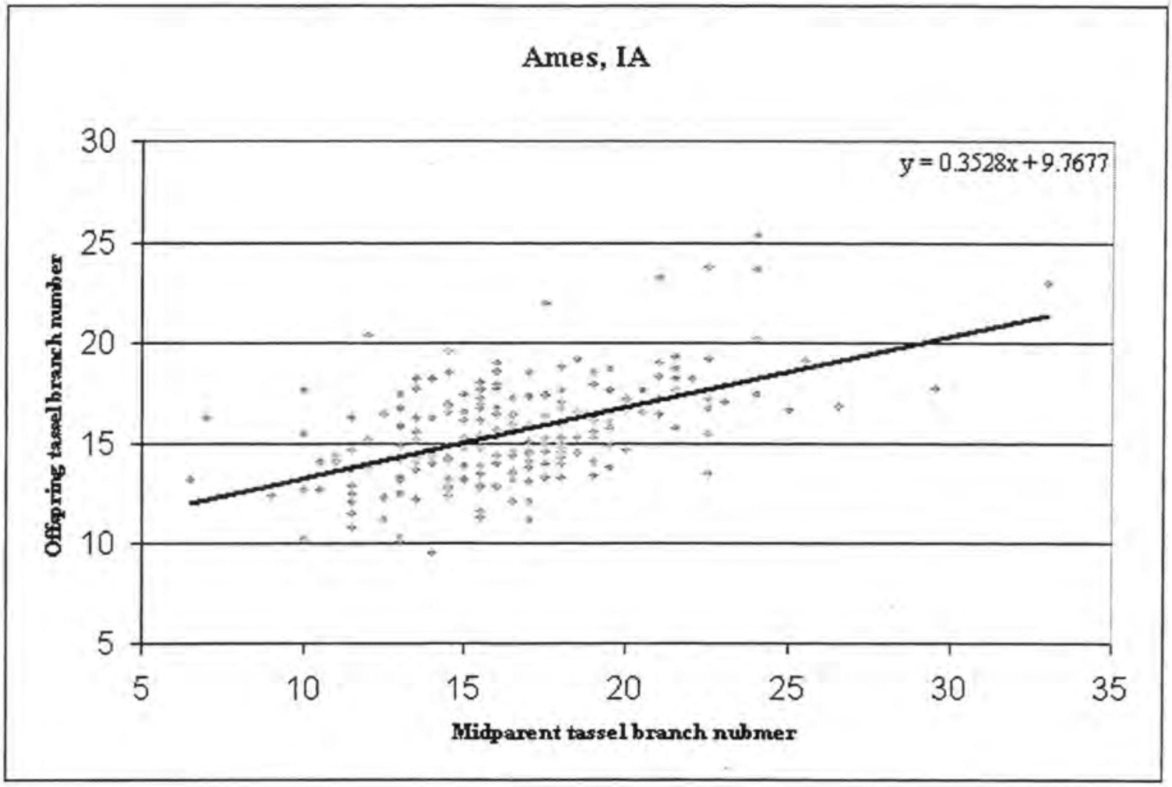


Figure D4. Midparent-offspring regression graphs of tassel branch number of maize at two environments in Iowa measured in 2001.



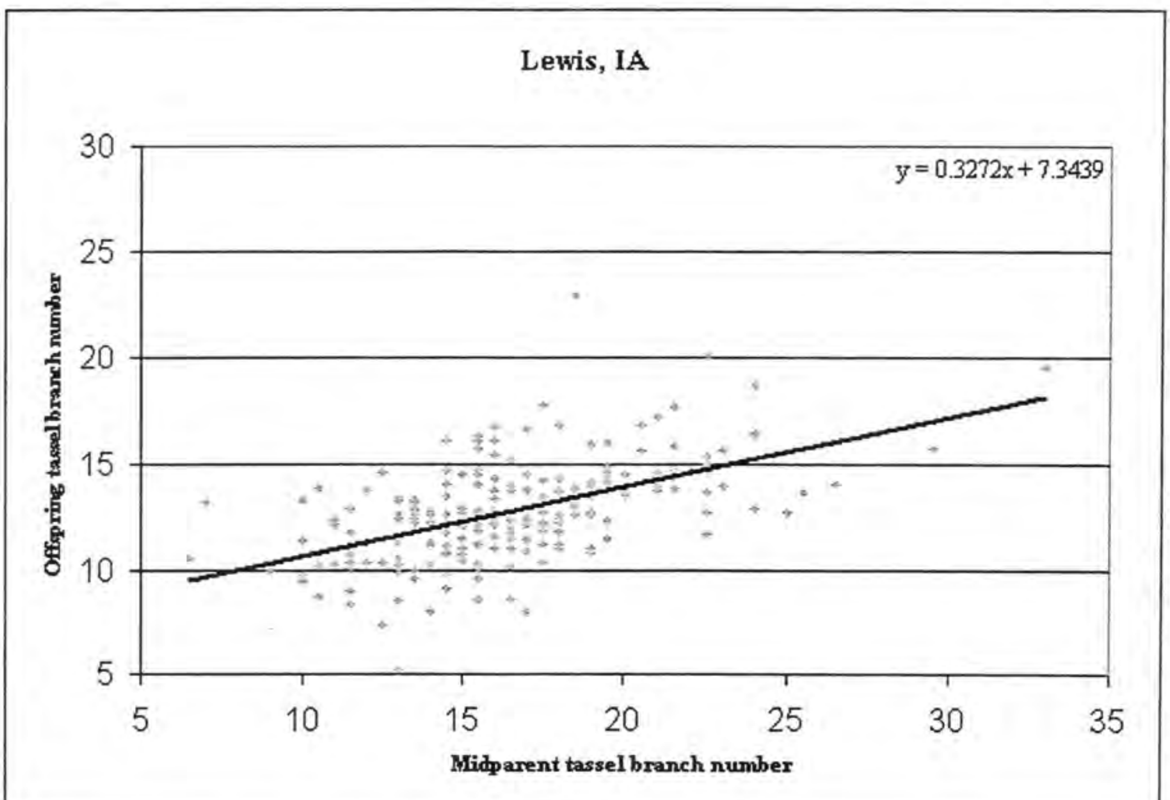
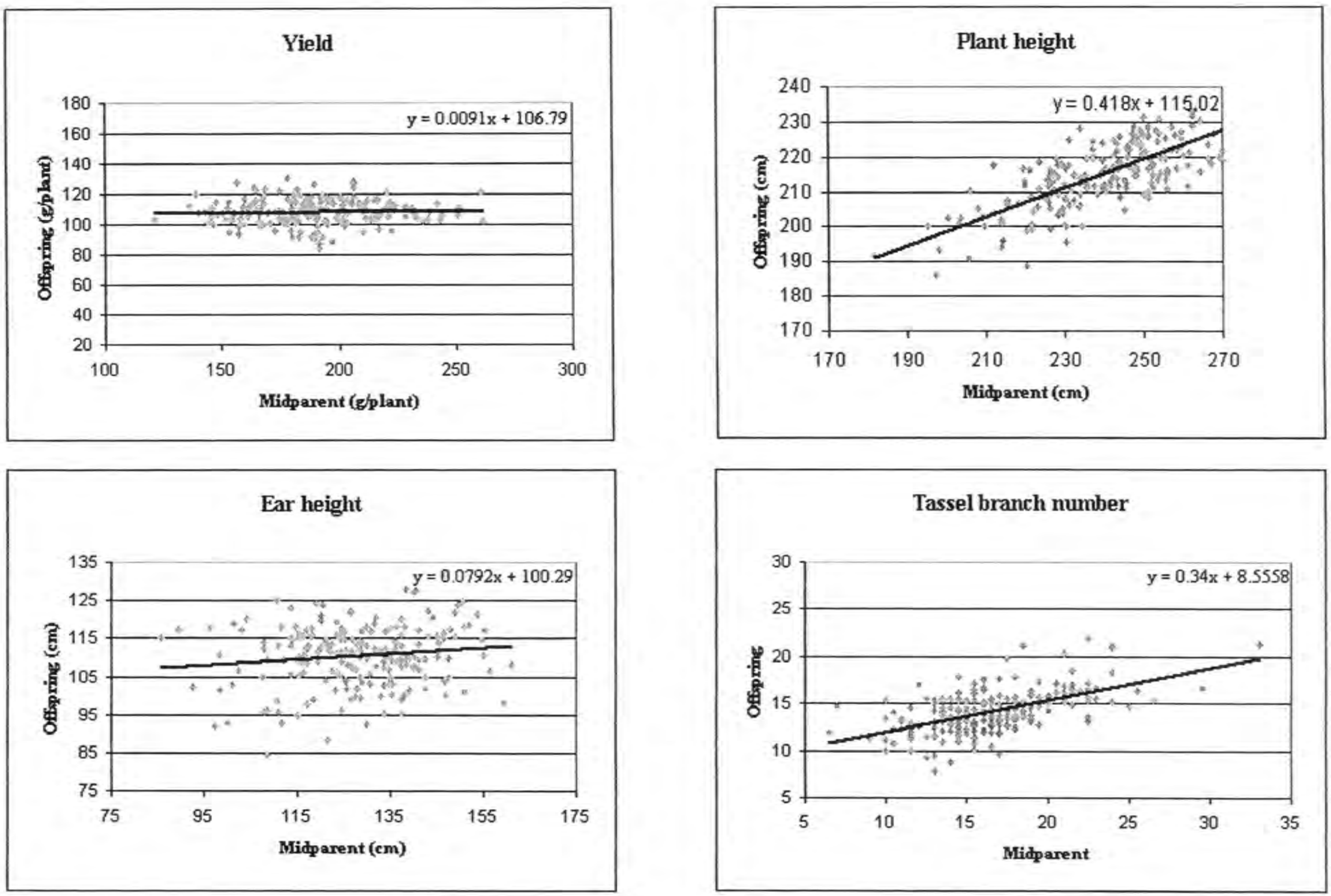


Figure D5. Midparent-offspring regression graphs of yield averaged over four environments and plant and ear height and tassel branch number averaged over two environments.



APPENDIX E

MEAN SQUARES FOR TRAITS COMBINED ACROSS ENVIRONMENTS

Table E1. Sources of variation, degrees of freedom for two environments, and mean squares from the analysis of variance for yield (g $plant^{-1}$) at four environments, plant and ear height (cm) and tassel branch number at two environments in maize.

Sources of variation	Df	MS	Yield	Plant height	Ear height	Tassel branch no.
Environments (E)	1		1193.06 **	14304.25 **	16104.76 **	959.99 **
Reps/environments	1					
Blocks/reps/environments	14					
Genotypes (G)	224	MS_3	541.63 **	160.47 **	120.64 **	9.91 **
S_0 Families (F)	208	MS_{31}	242.85 **	162.31 **	114.24 **	7.98 **
Checks (C)	15	MS_{32}	4512.54 **	69.19 ^{ns}	94.56 ^{ns}	20.33 ^{ns}
F vs. C	1	MS_{33}	4416.82 ^{ns}	1000.63 ^{ns}	1516.68 ^{ns}	309.91 **
Genotype x Environment	224	MS_2	163.60 *	57.04 **	45.33 **	5.02 **
F x E	208	MS_{21}	144.80 *	56.60 **	41.25 **	4.39 **
C x E	12	MS_{22}	292.00 *	68.81 *	103.34 **	16.24 **
(F vs. C) x E	1	MS_{23}	2275.37 **	7.32 ^{ns}	197.85 **	1.49 ^{ns}
Pooled error	435	MS_1	193.43	37.67	28.08	2.04
Total	899					

*, ** significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

APPENDIX F

MEAN SQUARES FOR TRAITS AT INDIVIDUAL ENVIRONMENTS TO CALCULATE BROAD-SENSE HERITABILITY FROM RANDOMIZED COMPLETE BLOCK ANALYSIS

Table F1. Sources of variation, degrees of freedom, and mean squares of four traits of maize grown at Ames, IA, 2001 when analyzed as a randomized complete block design.

Sources of variation	Df	MS	Yield	Plant height	Ear height	Tassel branch no.
Reps	1		497.34 ^{ns}	4291.20 ^{ns}	983.51 ^{ns}	21.95 ^{ns}
S_0 Families	208	MS2	240.98 ^{ns}	226.40 **	137.49 **	13.22 **
Error	208	MS1	194.82	58.01	30.80	1.98
Total	417					

*, ** significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

Table F2. Sources of variation, degrees of freedom, and mean squares of four traits of maize grown at Lewis, IA, 2001 when analyzed as a randomized complete block.

Sources of variation	Df	MS	Yield	Plant height	Ear height	Tassel branch no.
Reps	1		18.48 ^{ns}	100.80 ^{ns}	144.13 ^{ns}	0.27 ^{ns}
S_0 Families	205	MS2	208.44 **	218.92 **	159.75 **	11.13 **
Error	200	MS1	123.96	38.17	31.01	2.25
Total	406					

*, ** significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

Table F3. Sources of variation, degrees of freedom, and mean squares of four traits of maize grown at Ankeny and Crawfordsville, IA, 2001.

			Ankeny	Crawfordsville
Sources of variation	Df	MS	Yield	Yield
Reps	1		136.06 ns	785.60 ns
S_0 Families	208	MS2	529.85 **	208.40 **
Error	208	MS1	264.79	123.96
Total	417			

*, ** significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

APPENDIX G

PHENOTYPIC TRAIT CORRLEATIONS

Table G1. Phenotypic correlations of all family means of four traits of maize grown at Ames, IA, 2001.

Trait	Yield	Plant height	Ear height	Tassel branch no.
	(g $plant^{-1}$)	(cm)	(cm)	
Yield (g $plant^{-1}$)		0.094^{ns}	0.099^{ns}	-0.034^{ns}
Plant height (cm)			0.905**	0.459**
Ear height (cm)				0.505**

*, **, significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

Table G2. Phenotypic correlations of all family means of four traits of maize grown at Lewis, IA, 2001.

Trait	Yield	Plant height	Ear height	Tassel branch no.
	(g $plant^{-1}$)	(cm)	(cm)	
Yield (g $plant^{-1}$)		0.0732^{ns}	0.091^{ns}	0.024^{ns}
Plant height (cm)			0.886**	0.388**
Ear height (cm)				0.472**

*, **, significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

Table G3. Phenotypic correlations of all family means of four traits of maize combined across environments, 2001.

Trait	Yield	Plant height	Ear height	Tassel branch no.
	(g $plant^{-1}$)	(cm)	(cm)	
Yield (g $plant^{-1}$)		0.083^{ns}	-0.005^{ns}	-0.199^{ns}
Plant height (cm)			0.814**	0.124**
Ear height (cm)				0.259**

*, **, significant at 0.05 and 0.01 levels, respectively.
ns = nonsignificant

ACKNOWLEDGEMENTS

Many people deserve acknowledgement for their assistance in making my master's degree possible: Dr. Hallauer for the suggestion of the thesis problem, guidance throughout the work, and instruction both in the classroom and the cornfield; Paul White for practical advice on life and plant breeding; Andy Ross for suggestions and ideas throughout the process; Brian Alt for proof reading and moral support; and my parents for their belief I could finish.